TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA

VOLUME IX.
1921.

WITH FOURTEEN PLATES AND THIRTEEN FOLDING MAPS.

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CONTENTS.

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ROYAL SOCIETY OF SOUTH AFRICA.

VOL. IX.

CONTRIBUTIONS TO OUR KNOWLEDGE OF THE FRESHWATER ALGAE OF AFRICA.*

3. *Freshwater Algae (exclusive of Diatoms), mainly from the Transkei Territories, Cape Colony.*

By F. E. Fritsch, D.Sc. (Professor of Botany, East London College, University of London),

AND

Miss E. Stephens, B.A.† (South African College, Cape Town).

(With 29 figures in the text.)

A. Introductory Remarks.

The samples of freshwater Algae dealt with in the present communication were mainly collected in the district of Kentani from an altitude ranging from about 1200 feet to sea-level, although a certain number were gathered at Malan in the Willowvale District, from Quingolo in the Mqanduli District, and from N'quamakwe; apart from these, four samples were obtained from

* The first paper of this series was published in the 'Annales de Biologie Lacustre,' vii, 1914, pp. 40–59 (Plate I); the second in the 'Annals of the South African Museum,' ix, 1918, pp. 483–611. The earlier literature dealing with the freshwater algal flora of South Africa is considered in the latter paper.

† The second author is occupied in collecting and making arrangements for the collection of freshwater Algae in various parts of South Africa, and in supplying such details as to local conditions, etc., as may be required. The systematic working out of the collections is undertaken by the first author, who is solely responsible for this part of the present report. A large number of the figures have been drawn by Dr. E. J. Salisbury, to whom the authors are greatly indebted.

pools of the Buffalo River at King William's Town. The total number of species recorded (exclusive of Diatoms) is 146 belonging to 63 genera (or, if we exclude the samples from King William's Town, 141 species and 61 genera); these include six new species, a new subspecies, and thirteen new varieties, apart from a number of new forms.

According to Miss Pegler, who has been mainly instrumental in collecting these samples, the collections may be considered as fairly representative of the Kentani District, though no samples were taken from the largest rivers. If this is a fair statement the algal flora is very poor in many respects, especially in the paucity of Protococcales and in the scanty representation of most genera of Desmids. The latter were plentiful as a matter of fact only in samples 36 and 327, and only the genera *Closterium* and *Cosmarium* were at all commonly present. The great scarcity of species of *Euastrum* and *Staurastrum* is especially striking, and, although the same feature was noted in the collections from the Cape (see the second report of this series), it does not apply to South Africa generally, as is demonstrated in other collections in course of being worked out. The Zygnemaceae are relatively well represented, which is perhaps due to many of the samples having been taken from small, stagnant pools, whilst the rather marked preponderance of Blue-green Algae in many of the collections is a feature often associated with conditions unfavourable to the growth of green forms.

In her introduction to the Flora of Kentani Miss Pegler* remarks that Kentani is said to be drying up and that surface water is less, streams smaller, and marshes disappearing. Herein perhaps lies the explanation for the scanty algal flora.

Amongst points of special interest may be noted the extension of the range of *Pediastrum integrum* var. *pearsoni* (*P. pearsoni* G. S. West), the discovery of *Zygnema cyanospermum* Cleve in South Africa, and the finding of *Mougeotia uberosperma* W. and G. S. West, hitherto only recorded from Huilla in Angola.

The Diatom-flora, which is rather abundant, presented so many points of difficulty that, in order not to delay further the publication of these results, it has been thought advisable to omit it. A number of the Diatoms are, however, mentioned in the following enumeration of samples.

B. Enumeration of the Samples.

The following list serves as a key to the collections, the numbers of the samples only being cited in the subsequent systematic portion. With the exception of samples 78–87, which were collected by Mr. M. Lundie from Malan in the Willowvale District, all the samples were gathered by Miss A. Pegler, A.L.S., mainly from the district of Kentani. The numbers

* 'Annals of the Bolus Herbarium,' ii, 1916, p. 3.

cited refer to the general collection of South African Algae (*cf.* footnote † on p. 1).

17–25. In pools, partly sheltered by sedges, formed by a slow-running spring, Kentani, August 28, 1912. (*Gloeocystis infusionum*, *Ulothrix tenerrima*, *U. moniliformis*, *Oedogonium* sp., *Vaucheria* sp., *Closterium ehrenbergii*, *C. lanceolatum*, *C. acerosum*, *Zygnema pectinatum*, *Ophiocytium* spp., *Tribonema bombycinum* f. *minor*, *Oscillatoria tenuis*, *Lyngbya* spp., *Euglena spirogyra*, *Trachelomonas* spp., *Nitzschia sigmoidea*, *Gomphonema gracile*, *Stauroneis phoenicenteron*, *S. anceps*, *Synedra ulna*, *Cymbella naviculiformis*, *Pinnularia hemiptera*, *P. madagascariensis*, *Navicula producta*, *N. vulgaris*.)

26. On rock in running stream, Kentani, September 20, 1912. (The main mass a foliose Liverwort, with *Closterium moniliferum*, *Pleurotaenium ehrenbergii*, *Cosmarium granatum*, *C. subcrenatum*, and a number of Diatoms —*Synedra* spp., *Nitzschia sigmoidea*, *N. tryblionella* var. *levidensis*, *Amphipleura pellucida*, *Gomphonema intricatum*, *Cymbella helvetica*, *Navicula radiosa*.)

28. On leaves, in closed pool, Kentani, September 20, 1912. (*Ulothrix tenerrima*, *Oscillatoria tenuis*, *Synedra ulna*, *Nitzschia sigmoidea*, *Gomphonema* spp., *Achnanthes minutissima*, *Navicula bicapitata*, *N. radiosa*.)

29, 30. In a stream, stagnant through drought, Kentani, September 24, 1912. Reddish-yellow deposit due to iron-bacteria. (*Ulothrix tenerrima*, *Oedogonium* sp., *Ophiocytium gracilipes*, *Tribonema bombycinum* f. *minor*, *Anabaena inaequalis* (?), *Euglena spirogyra*, *Trachelomonas* spp., and various Diatoms.)

31. Pool in connection with slow spring, Kentani, October 12, 1912. (*Chlamydomonas* sp. (*Palmella*-stage), *Nitzschia sigmoidea*.)

32. On muddy bank, Kentani, October 12, 1912. (Iron-bacteria and *Navicula mesolepta*, *Nitzschia sigmoidea*.)

33. Attached to submerged rock in running water, Kentani, November 11, 1912. (*Spirogyra* sp., *Synedra ulna*.)

35. Kentani, November, 1912. (Leafy Liverwort with *Closterium moniliferum*, *Synedra* spp.)

36. Kentani, November, 1912. (*Oocystis solitaria*, *Oedogonium pusillum* forma, *Cylindrocystis brebissonii* and var. *minor*, *Penium minutum* var. *productum* n. var., *Closterium parvulum*, *Euastrum submontanum* n. sp., *Cosmarium quadratum* var. *africanum* n. var., *Zygnema pectinatum*, *Mougeotia uberosperma*, *Glaucocystis nostochinearum*, *Stigonema turfaceum*, *Eunotia* spp.)

64, 65. In half-stagnant, exposed pools, Kentani, August 6, 1912. (*Closterium moniliferum*, *Cosmarium meneghinii* f. *africana*, *Spirogyra majuscula*, *Zygnema* sp., *Mougeotia* sp., *Synedra* spp.)

66. Open stagnant pools, Kentani, July 24, 1912. (*Vaucheria* sp., *Spirogyra* sp., *Mougeotia* sp., *Synedra pulchella*.)

67. Slime on mud in exposed drying bed of stream, Kentani, July 24, 1912. (*Euglena* sp.)

68. Pools of Buffalo River at King William's Town, December, 1912. (*Phormidium inundatum, Nitzschia palea.*)

69. Pools of Buffalo River at King William's Town, December, 1912. (*Phormidium autumnale, Trachelomonas volvocina, Nitzschia stagnorum, Achnanthes coarctata.*)

70, 71. Pools of Buffalo River at King William's Town, December, 1912. (*Pediastrum tetras* var. *apiculatum* n. var., *Tetraedron minimum, Scenedesmus quadricauda* and var. *abundans, Stigeoclonium falklandicum* (?), *Cosmarium subcrenatum, Spirogyra rivularis* (?), *Chroococcus minor, Phormidium tenue, Trachelomonas volvocina, Cyclotella operculata, Gomphonema lanceolatum, Synedra* spp., *Cymbella* sp., *Navicula producta, N. viridula.*)

78. Slime on stagnant water of marsh, Malan, Willowvale District, February 11, 1913. (Mainly iron-bacteria, with fragments of *Spirogyra, Cladophora,* and Blue-green Algae.)

79. On rock, over which Ngadu River runs, Malan, Willowvale District, February 10, 1913. (*Cladophora glomerata, Phormidium autumnale, Synedra pulchella, Nitzschia sigmoidea, Gomphonema acuminatum* forma.)

81. Clinging to damp rock, Malan, Willowvale District, February 11, 1913. (*Phormidium laminosum, Calothrix* sp.)

82. On rock over which Ngadu River runs, Malan, Willowvale District, February 10, 1913. (*Phormidium autumnale, Nostoc caeruleum, Synedra pulchella.*)

84. Slime on rock over which water has been running, Malan, Willowvale District, February 10, 1913. (*Phormidium autumnale.*)

85. In standing water, Malan, Willowvale District, February 11, 1913. (*Closterium moniliferum, C. pritchardianum* forma, *Spirogyra decimina* f. *fuellebornei, Zygnema* sp., *Aphanothece microscopica, Phormidium tenue, Nostoc muscorum, Calothrix* sp. (*adscendens* ?), *Synedra ulna.*)

86. In slow-running water of marsh, Malan, Willowvale District, February 11, 1913. (Fragments of *Nitella* with *Oedogonium* sp., *Bulbochaete* sp., *Cosmarium hammeri* and var. *africanum* n. var., *C. capense, C. laeve, C. punctulatum, C. quadrum* var. *minus, Spirogyra* sp., *Zygnema* sp., *Tribonema bombycinum* f. *minor, Oscillatoria brevis, Synedra* spp., *Eunotia lunaris, Gomphonema angustatum.*)

87. In marshy ground, Malan, Willowvale District, February 11, 1913. (*Nostoc* sp.)

99. Half-stagnant pool, sheltered by trees, Kentani, February 1, 1913. (*Gonium pectorale, Eudorina elegans, Euglena* sp., *Synedra ulna, Nitzschia acicularis.*)

100. Rain-washed ground, where grass has been removed, Kentani, March 29, 1913. (*Hormidium flaccidum.*)

158. In pools, Quingolo, Mqanduli District, December 23, 1913. Red deposit due to iron-bacteria. (*Chlamydomonas* sp., *Scenedesmus quadricauda* var. *horridus*, *Closterium pegleri* n. sp., *Cosmarium granatum*, *C. capense*, *C. laeve* forma, *Chroococcus turgidus*, *Coelosphaerium kuetzingianum*, *Oscillatoria limosa*, *Trachelomonas hispida*, *Synedra ulna*, *Cymbella helvetica*, *Gyrosigma acuminatum*, *Rhopalodia gibba*, *Surirella ovalis* forma, *Stauroneis acuta*, *Pinnularia dactylus*, *Navicula vulpina*, *N. viridula*, *N. ovalis*.)

159. In pools, Quingolo, Mqanduli District, December 23, 1913. (*Pediastrum integrum* var. *pearsoni*, *Scenedesmus quadricauda* var. *horridus*, *Coelastrum microporum*, *Dictyosphaerium pulchellum*, *Spirogyra* sp., *Oedogonium pringsheimii*, *Bulbochaete* sp., *Closterium pegleri* n. sp., *Cosmarium botrytis*, *Staurastrum striolatum*, *Zygnema* sp., *Chroococcus turgidus*, *Gloeothece* spp., *Gomphosphaeria aponina*, *Merismopedia glauca*, *M. punctata*, *Phormidium valderianum*, *Synedra pulchella*, *Cymbella* spp., *Denticula denticula*, *Achnanthes exilis*, *Gomphonema gracile* var. *dichotoma*, *Surirella ovalis*, *Epithemia zebra*, *Stauroneis acuta*, *Navicula vulpina*, *Cymatopleura solea*.)

160. On dry rocks, within reach of swollen river, Quingolo, Mqanduli District, December 23, 1913. (Fragments of *Nitella* with *Synedra pulchella* and *Cymbella cymbiformis*.)

161. Stagnant pool, Umtata Park, January 10, 1914. (*Oscillatoria* spp., *Euglena* spp., *Synedra ulna*, *Nitzschia palea*, *N. stagnorum*, *N. tryblionella*, *Surirella ovalis*, *Navicula exilis*, *N. mutica*.)

311. On decayed *Typha* in exposed stream, Quingolo, Mqanduli District, October 21, 1916. (*Gloeocystis vesiculosa*, *Pediastrum* spp., *Scenedesmus bijugatus*, *Geminella interrupta*, *Chaetosphaeridium globosum*, *Oedogonium varians* (?), *Bulbochaete* sp., *Cosmarium* spp., *Spirogyra* sp., *Zygnema cyanospermum* forma, *Mougeotia* sp., *Chroococcus turgidus*, *Merismopedia glauca*, *Peridinium* sp., and various Diatoms.)

312. Exposed stream, Quingolo, Mqanduli District, October 21, 1916. (Same as last with *Scenedesmus quadricauda* and var. *dispar*, *Closterium moniliferum*, *Cosmarium meneghinii* f. *africana*, *C. sportella* var. *simplex* n. var., *Zygnema* sp., *Gomphosphaeria aponina*, *Oscillatoria animalis*, *Trachelomonas volvocina*.)

313. Exposed stream, Quingolo, Mqanduli District, October 21, 1916. (*Spirogyra* sp. with *Cymatopleura* and other Diatoms.)

314. Exposed stream, Quingolo, Mqanduli District, October 21, 1916. (Similar to 312, though with fewer species.)

315. Floating dark slime, in exposed stream, Quingolo, Mqanduli District, October 21, 1916. (Similar to 312, but with fewer species. Also present: *Closterium leibleinii*, *Nitzschia acicularis* and other species, *Gyrosigma acuminatum*.)

316. Exposed stream, Quingolo, Mqanduli District, October 21, 1916, (*Spirogyra decimina* var. *inflata* n. var., *Spirogyra* sp., *Zygnema* sp., and a few Diatoms.)

323. On water-plants in brackish water, Gogwana mouth, April 1, 1915. (*Enteromorpha basiramosa* n. sp., *Cladophora* sp., and numerous Diatoms.)

324. In exposed pool, formed by spring-water trickling on to beach, Kentani, April 1, 1915. (*Chroococcus turgidus, Gloeothece linearis, Microcystis* spp., *Oscillatoria* spp., *Phormidium fragile, Lyngbya aestuarii, Microcoleus chthonoplastes, Anabaena torulosa, Gyrosigma* sp., *Amphora* sp. and numerous other Diatoms.)

325. On rocks, where spring-water meets sea-water, Kentani, April 3, 1915. (*Enteromorpha basiramosa* n. sp., *Cladophora* sp., *Gomphosphaeria aponina, Chamaesiphon incrustans*, and numerous Diatoms.)

326. About fifty yards from the mouth of the Qolora River, Kentani, April 3, 1915. (*Chroococcus* spp., *Gomphosphaeria aponina, Oscillatoria* spp., *Spirulina major, Phormidium subfuscum, Melosira* sp., and other Diatoms.)

327. Slightly exposed stream at an altitude of 1200 ft., Kentani, March 24, 1915. (*Pediastrum te'ras, Ankistrodesmus falcatus, Coleochaete scutata, Oedogonium* spp., *Penium margaritaceum* var. *irregularius, Closterium* spp., *Pleurotaenium* spp., *Euastrum simpliciforme* n. sp., *Cosmarium pachydermum* var. *tuberculatum* n. var., *C. undulatum* var. *crenulatum C. hammeri* var. *africana* n. var., *C. granatum* forma and var. *africanum* n. var., *C. capense, C. regnellii* forma, *C. laeve* formae, *C. subprotumidum* and subsp. *simplex* n. subsp., *C. botrytis* var. *pegleri* n. var., *C. gayanum* var. *rotundata* n. var., *C. quadrum* forma, *Spirogyra bellis, Spirogyra* sp., *Zygnema* sp., *Mougeotia* sp., *Anabaena* sp., *Scytonema* (*stuposum?*), *Calothrix gracilis* f. *flexuosa, Synedra ulna* var. *splendens, Stauroneis phoenicenteron, Navicula ovalis*, and numerous other Diatoms.)

328. Slow-running stream in the shade, Kentani, April 10, 1915. (Only iron-bacteria.)

329. On floating *Phragmites* stem, about a mile from the mouth of the Qolora, Kentani, April 18th, 1915. (Fragments of *Entermorpha basiramosa* n. sp., *Rhizoclonium hieroglyphicum, Cladophora* sp., *Oedogonium* sp., *Closterium ehrenbergii* (?), *Lyngbya aerugineo-coerulea, Calothrix* sp., and Diatoms.)

330. On floating *Phragmites* stem, about a mile from the mouth of the Qolora, Kentani, April 18, 1915. (*Enteromorpha basiramosa* n. sp., *Oedogonium* sp., and Diatoms.)

331. On sheltered stones, in clear, running water, Kentani, about 1200 ft., April 19, 1915. (*Scenedesmus quadricauda, Oedogonium* spp., *Cosmarium quadrum* forma, *Spirogyra fluviatilis* var. *africana* n. var., *Chamaesiphon incrustans*, and Diatoms.)

332. Scrapings off wood and stone, near homestead, Kentani, about 1200 ft., May 2, 1915. (*Pleurococcus vulgaris*, *Hormidium flaccidum*.)

333. Marshy ground, Kentani, 1200 ft., May 1, 1915. (Diatoms only.)

334. Marshy ground, Kentani, 1200 ft., May 1, 1915. (*Oedogonium* sp., *Vaucheria* sp., *Closterium* spp., *Tribonema bombycinum* f. *minor*, and Diatoms.)

335. Exposed clear running stream, Kentani, altitude 1200 ft., May 5, 1915. (*Oscillatoria subtilissima*, *Nostoc* sp. (*verrucosum*?) *Calothrix* sp.)

336. Sheltered marshy spot, Kentani, about 1200 ft., May 2, 1915. (*Closterium* spp., *Cosmarium quadrum* forma, *Spirogyra* sp., *Oscillatoria tenuis*, *Chantransia chalybea*, and Diatoms.)

337. Stagnant pool, near stream, Kentani, 1200 ft., May 24, 1915. (*Closterium moniliferum*, *Synedra ulna*.)

338. Open vlei near Gogwana mouth, July, 1915. (*Sphaerocystis schroeteri*, *Ulothrix subtilissima*, *Closterium* spp., *Spirogyra subreticulata* n. sp., *Ophiocytium* spp., *Phacus* spp., *Eunotia lunaris*, *Fragilaria* sp., and other Diatoms.)

339. The same, epiphytes on *Nitella* and other water-plants. (Similar to 338, but with *Pleurococcus dissectus*, *Bulbochaete* sp.)

340. The same. (Similar to 338, but with *Trochiscia stagnalis*, *Euglena* sp.)

341. Slow-running stream, near Gogwana mouth, July, 1915. (*Oedogonium* sp., *Cosmarium meneghinii*, and Diatoms.)

342. Sheltered mouth of slow stream near Gogwana mouth, July, 1915. (*Oedogonium* sp., *Tribonema bombycinum* f. *minor*, *Synedra* spp., and other Diatoms.)

343. The same, on dead leaves. (*Coleochaete orbicularis*, and a few Diatoms.)

344. Trickle of water on road, passing through small wood, N'quamakwe, 2500 ft., June 27, 1917. (*Vaucheria sessilis* f. *repens*, *Spirogyra* sp., *Synedra* spp., *Achnanthes* spp., *Surirella* sp., etc.)

345. Scrapings from side of tank, containing spring-water, N'quamakwe, 2500 ft., July 5, 1917. (*Chlorococcum* sp. (? Fig. 1), *Pediastrum tetras* var. *apiculatum* n. var., *Oocystis rupestris*, *Scenedesmus bijugatus*, *Ulothrix variabilis*, *Cosmarium* spp., *Schizothrix calcicola*, *Calothrix* sp., and Diatoms.)

346. Roadside puddle formed by drying surface spring, N'quamakwe, 2500 ft., July 5, 1917. (*Closterium pritchardianum* forma, *C. pseudolibellula* n. sp., *Tribonema bombycinum* f. *minor*, *Oscillatoria geminata*, *Euglena* sp.)

Previous records for South Africa are given under the individual species. The number of new records for South Africa in the present communication is seventy-two.

C. Systematic Enumeration of the Species Observed.

1. ISOKONTAE.

(*a*) CHLAMYDOMONADALES.

(2) CHLAMYDOMONADACEAE.

Genus CHLAMYDOMONAS Ehrenberg.

(Note.—Individuals of this genus, which were either too scanty or too imperfectly preserved to render determination possible, were observed in samples 31—here as a very abundant *Palmella*-stage—and 158.)

(5) VOLVOCACEAE.

Genus GONIUM Mueller.

1. *Gonium pectorale*, Mueller, Verm. terrestr. et fluviat., etc., i, 1773, p. 60.

Sample 99 (very rare).

Genus EUDORINA Ehrenberg.

1. *Eudorina elegans*, Ehrenberg, Infusionsthiere, 1851, p. 78, Pl. II, fig. 10.

Sample 99 (rare).

Previously recorded from Cape Colony and Orange Free State (Fritsch).

(*c*) TETRASPORALES.

(1) SPHAEROCYSTACEAE.

Genus SPHAEROCYSTIS Chodat.

1. *Sphaerocystis schroeteri*, Chodat, Études d. Biol. lacustre, Bull. d. l'Herb. Boissier, 1897, p. 292, Tab. IX; Alg. vert. de la Suisse, Berne, 1902, p. 114, fig. 53.

Samples 338, 339 (rare).

Previously recorded from Cape Colony (Fritsch).

(3) PALMELLACEAE.

Genus GLOEOCYSTIS Naegeli.

1. *Gloeocystis infusionum* (Schrank), G. S. West, Brit. Freshw. Algae, 1904, p. 246, fig. 113, A–E. (Syn.: *Chlorococcum infusionum* (Schrank), Menegh.)

Samples 20, 21 and 24.

2. *Gloeocystis vesiculosa*, Naegeli, Gatt. einzell. Alg., 1849, p. 65, 66, Tab. IV, F.

Samples 311, 312.

(*d*) PROTOCOCCALES.

(1) CHLOROCOCCACEAE.

Genus CHLOROCOCCUM Fries.

1. *Chlorococcum* sp. (?) (Fig. 1).

Sample 345 (common).

This form occurred in the shape of isolated, generally completely spherical cells, of rather varying dimensions (diam. 20–36 μ). The wall in most cases was moderately thick, with a well-defined outer "cuticle," but now and again cells were encountered with a much thicker stratified membrane (Fig. 1, *A*). The cell-contents not uncommonly occupied the whole interior (Fig. 1, *A*); some of the cells, however, possessed more or less contracted contents and, in such cases, one or more oil-drops were almost invariably present between the wall and the protoplast (Fig. 1, *B*). In many of the cells a small spherical body was visible in the middle of the protoplast (Fig. 1, *A* and *B*). This appeared to be the nucleus, since

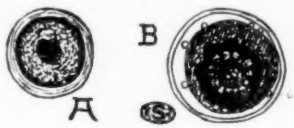


Fig. 1.—*Chlorococcum* sp. (?). *A*, cell with thick stratified wall, showing the central nucleus (?). *B*, cell with contracted contents, showing small oil-drops and ring of starch near centre of contents. × 650.

starch was not detected in the immediate vicinity. Pyrenoids seemed to be absent, but there was commonly a ring-shaped zone of starch (Fig. 1, *B*), lying about midway between the surface of the protoplast and the centre of the cell. The chloroplast was difficult to decipher, but such indications as were obtainable hint at its being spherical. For this reason this form is provisionally referred to the genus *Chlorococcum*, although in the absence of all reproductive stages the reference must remain doubtful.

(4) HYDRODICTYACEAE.

Genus PEDIASTRUM Meyen.

1. *Pediastrum tetras* (Ehrenb.), Ralfs, Ann. and Mag. Nat. Hist., xiv, 1844, p. 469, Pl. XII, fig. 4; Brit. Desm., 1848, p. 182, Tab. XXXI, fig. 1. (Syn.: *P. ehrenbergii* Corda.)

Samples 311, 312, 327, 345.

Never very abundant; 4–8-celled colonies.

Previously recorded from Cape Colony (Fritsch).

Var. *apiculatum*, F. E. Fritsch, nov. var. (Fig. 2).

Coenobiis e cellulis 4 vel 8 (disp.: 7–1) constantibus; cellulis marginalibus processibus 2 plus minus divergentibus, in apice paullo dilatatis et membrana incrassata; inter cellulas marginales membrana exterior saepe est incrassata et plus minus prominens forma apiculi. Lat. colon. 4-cell., 22 μ; lat. colon. 8-cell., 24–40 μ; lat. cell., 9–16 μ.

Samples 71 (rare) and 345 (rather rare).

It is possible that this should be regarded as a separate species, but the relatively little material available was not sufficient to settle this point. In particular the four-celled stage (Fig. 2, *D*), bears, except for the characteristic apiculus at the end of each marginal process, a considerable

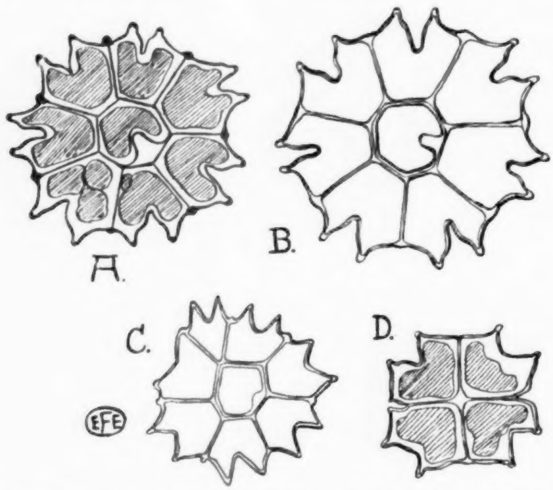


FIG. 2.—*Pediastrum tetras* (Ehrenb.), Ralfs, var. *apiculatum*, F. E. Fritsch, nov. var. *A* and *B*, eight-celled, *D*, four-celled colonies; *C*, abnormal colony. × 1000.

resemblance to some of the simpler colonies of *P. tetras* (*cf.* especially Ralfs, *loc. cit.*, Tab. XXXI, fig. 1, *D*). It is to be noticed that the depth of the incision between the marginal processes, as well as the shape of the latter, are rather variable. On the whole the incision tends to be wider and blunter than in the type; this applies also to the single, centrally placed, cell of the eight-celled colonies.

A second characteristic of the variety, apart from the apiculate processes, lies in the presence of a more or less marked thickening of the external membrane at a point coinciding with the septum between two marginal cells (Fig. 2, *A*, *B*, *C*); in some cases this thickening is so marked as to amount to a definite projection.

2. ***Pediastrum integrum***, Naegeli, *op. cit.*, pp. 96, 97, Tab. V, B, fig. 4.

var. *pearsoni* (G. S. West), F. E. Fritsch. (Syn.: *P. pearsoni*, G. S. West, Freshw. Algae, Percy Sladen Memorial Exped., etc., Ann. S. Afr. Mus., ix, 1912, p. 79, figs. 30–32.) (Fig. 3.)

Samples 159, 311, 312, 314, 315 (especially common in 312).

An examination of the extensive material in the present samples has shown that *P. pearsoni* is not sufficiently distinct from *P. integrum* to

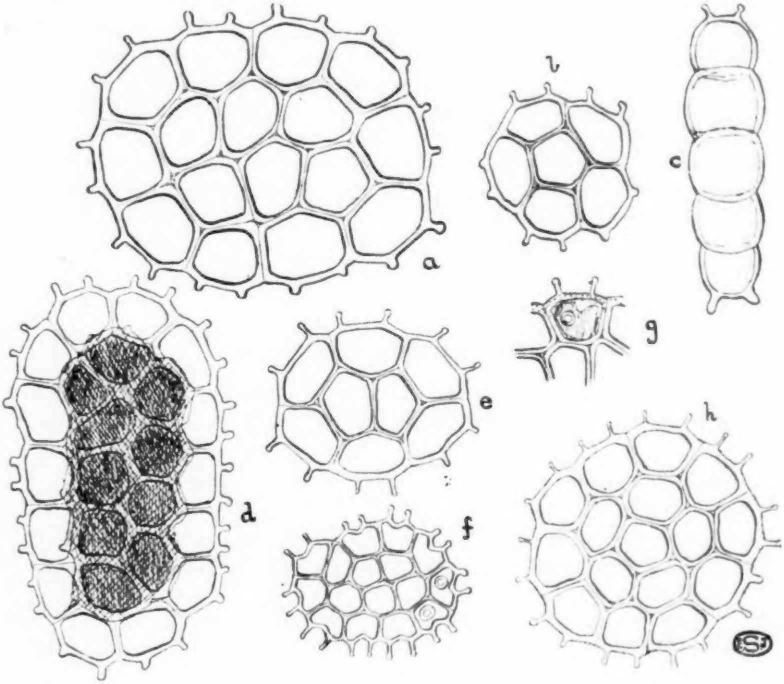


FIG. 3.—*Pediastrum integrum*, Naeg., var. *pearsoni* (G. S. West), F. E. Fritsch. *c* in side view; in *g* the chloroplast and scrobiculation of the cell-wall are shown; in *d* the superincumbent cells are shaded. *f*, young colony (?). All figures × 600.

warrant the establishment of a separate species. The only marked points of difference are: (a) the subcapitate character of the short processes borne by the marginal cells—a feature which is not always pronounced (*cf.* Fig. 3, *a* and *d*); (b) the fact that these processes are not situated in the same plane (*cf.* especially fig. 3, *c* and West's fig. 31); (c) the minute scrobiculation of the membrane. As minor points of difference may be noted the not uncommon elliptical shape of the cells (Fig. 3, *e*, and West's fig. 30).

which are, however, often isodiametric as in the typical *P. integrum*, and a tendency towards rounding off of the angles.

Other features of West's diagnosis do not hold good. Thus, the colonies are by no means always elliptical in outline (*cf.* Fig. 3, *a*, *e*, and *h*), and the number of component cells is subject to very considerable variation, as a reference to the figures will show; colonies consisting of 15 cells have not, however, been observed, and this is perhaps an abnormal condition. The following numbers and arrangements of the cells were encountered: 6 (5–1), 8 (6–2), 16 (10–6, 11–5, 10–5–1, 9–6–1); colonies with still more numerous cells, not uncommonly arranged in two layers, are not infrequent (Fig. 3, *d*).

The type of colony, shown in Fig. 3, *f*, is probably to be regarded as a young stage. It differs from the others in the smaller size of its cells, and in the fact that the outer edge of the marginal cells, between the two processes, is usually markedly retuse. Slight indications of this retuse character are at times to be found even in the large-celled colonies. It is noticeable that in this small-celled form the processes have attained their full dimensions.

(5) CHLORELLACEAE.

Genus TROCHISCIA Kuetzing.

1. *Trochiscia stagnalis*, Hansgirg, Prodr. d. Algenfl. v. Boehmen, ii, 1892, p. 241. (Syn.: *Acanthococcus palustris*, Hansgirg. *op. cit.*, i, 1888, p. 274.)

Sample 340 (very rare).

Genus TETRAEDRON Kuetzing.

1. *Tetraedron minimum* (A. Br.), Hansgirg, Ueb. d. Suesswasseralg.-Gatt. *Trochiscia*, etc., Hedwigia, xxvii, 1888, p. 131. (Syn.: *Polyedrium minimum*, A. Br.)

Sample 71.

Previously recorded from the Karoo and Little Namaqualand (G. S. West).

(6) OOCYSTACEAE.

Genus OOCYSTIS Naegeli.

1. *Oocystis solitaria*, Wittrock, in Wittr. et Nordst., Alg. exsicc., No. 244, Bot. Notiser, 1879, p. 27; Printz, Uebers. ueb. d. Gatt. *Oocystis*, Nyt Mag. f. Naturvidenskab., li, 1913, p. 183, Tab. V, figs. 36–39.

Sample 36.

Long. cell., 23–25 μ; lat., 12–16 μ.

Previously recorded from Cape Colony and Orange Free State (Fritsch).

2. *Oocystis rupestris*, Kirchner, Beitr. z. Algenfl. v. Wuertemberg, Jahreshefte d. Ver. f. vaterl. Naturk. in Wuertemberg, xxxvi, 1880, p. 169, Tab. II, fig. 2; Printz, *op. cit.*, p. 174, Tab. IV, figs. 7–9.
Sample 345.
Previously recorded from Cape Colony (Fritsch).

(7) SCENEDESMACEAE.

Genus SCENEDESMUS Meyen.

1. *Scenedesmus quadricauda* (Turp.), Brébisson, Alg. Falaise, 1835, p. 66; Brunnthaler, Syst. Uebers. *Scenedesmus*, Hedwigia, liii, p. 168, fig. 16.
Forma *typica*.
Samples 71, 312, 331.

Var. *abundans*, Kirchner, Kryptogamenfl. Schlesien, ii, 1878, p. 98; Brunnthaler, *op. cit.*, p. 168, fig. 18.
Sample 71.

Var. *dispar* (Bréb.), Brunnthaler, *op. cit.*, pp. 168, 171. (Syn.: *S. dispar*, Bréb.)
Sample 312.

Var. *horridus*, Kirchner, *op. cit.*, p. 98; Brunnthaler, *op. cit.*, p. 168.
Samples 158, 159.
The type and var. *dispar* previously recorded from Cape Colony (Fritsch); the type from the Karoo, Holle River, and Little Namaqualand (G. S. West).

2. *Scenedesmus bijugatus* (Turp.), Kuetzing, Synops. Diat., Linnaea, viii, 1833, p. 607. (Syn.: *S. obtusus*, Meyen.)
Samples 311, 345.
Previously recorded from Cape Colony (Fritsch), the Karoo and Little Namaqualand (G. S. West).

Genus COELASTRUM Naegeli.

1. *Coelastrum microporum*, Naegeli, in A. Braun, Alg. unicell., etc., 1855, p. 70.
Sample 159.
Previously recorded from Cape Colony (Fritsch).
f. irregulare, F. E. Fritsch, Freshw. Alg. S. Orkneys, Journ. Linn. Soc., Bot., xl, 1912, p. 328, fig. H.
Sample 312.

Genus DICTYOSPHAERIUM Naegeli.

1. *Dictyosphaerium pulchellum*, Wood, Freshw. Alg. N. America, Smithsonian Contrib., xix, No. 241, 1872, p. 84, Pl. X, fig. 4.

Sample 159 (very rare).

Genus ANKISTRODESMUS Corda (RHAPHIDIUM Kuetz.).

1. *Ankistrodesmus falcatus* (Corda), Ralfs, Brit. Desm., 1848, p. 180. (Syn.: *Rhaphidium fasciculatum*, Kuetz.; *R. polymorphum*, Fresen., var. *falcatum*, Rabenh.)

Sample 327 (rare).

Previously recorded from Cape Colony and Orange Free State (Fritsch).

Addendum: Genus of doubtful position. PLEUROCOCCUS Menegh.

1. *Pleurococcus vulgaris*, Meneghini, Monogr. nostoch. Ital., Att. R. Acad. Sci. Torino, ser. 2, v, 1842, p. 38, Pl. V, fig. 1.

Sample 332.

2. *Pleurococcus dissectus* (Kuetz.), Naegeli, Gatt. einzell. Alg., 1849, p. 65, Tab. IV, E, fig. 3. (Syn.: *Protococcus dissectus*, Kuetz.)

Sample 339 (attached to various substrata, especially common on *Utricularia* sp.).

This species is evidently of wide distribution in the Southern Hemisphere. It has been recorded by G. S. West from Angola and plays an important part in the Antarctic algal flora. In all these cases, as in the present instance, the species grows submerged, whereas in other regions it is subaërial.

(*e*) ULOTRICHALES.

(1) ULOTRICHACEAE.

Genus ULOTHRIX Kuetzing.

1. *Ulothrix subtilissima*, Rabenhorst, Krypt. Flora v. Sachsen, etc., I, 1863, p. 263; Heering, Ulotrichales, etc., in Pascher, Suesswasserfl. Deutschlands, etc., vi, 1914, p. 32, fig. 27.

Samples 338, 339, 340 (in all cases rare).

Previously recorded from Cape Colony (Fritsch).

2. *Ulothrix tenerrima*, Kuetzing, Phyc. gen., 1843, p. 253, Pl. IX, fig. 1; Heering, *op. cit.*, p. 32, figs. 28–30.

Samples 20, 21, 28, 29.

Previously recorded from Little Namaqualand (G. S. West).

3. *Ulothrix variabilis*, Kuetzing, Spec. Alg., 1849, p. 346; Heering, *op. cit.*, p. 32, fig. 27.

Sample 345 (common).

Previously recorded from Cape Colony (Fritsch).

4. *Ulothrix moniliformis*, Kuetzing, Spec. Alg., 1849, p. 347; Heering, *op. cit.*, p. 33, fig. 32.

Sample 24 (?).

Cells definitely constricted; diam. 14–15 μ.

[NOTE.—Fragments of a species of this genus were also present in sample 17.]

GENUS HORMIDIUM KLEBS.

1. *Hormidium flaccidum*, A. Braun; Heering, *op. cit.*, p. 46, figs. 48, 49.

Samples 100, 332 (in the latter case rather fragmentary).

GENUS GEMINELLA TURPIN.

1. *Geminella interrupta*, Turpin, Mém. d. Mus. d'hist. nat., xvi, 1828, p. 329, Tab. XIII, fig. 24; Heering, *op. cit.*, p. 41, fig. 45.

Samples 311, 312, 314 (rather common in 311).

Lat. cell., 6–7 μ; long. cell., ad 15 μ; lat. vag., ad 33 μ.

(2) ULVACEAE.

GENUS ENTEROMORPHA LINK.

1. *Enteromorpha basiramosa*, F. E. Fritsch, n. sp. (Figs. 4, 5).

E. parva, ad 2 cm. longa, rupibus vel plantis aquaticis adhaerens; thallo angustissimo tubuloso, ad basin copiose insuper parcissime ramoso, ramis in parte superiore plerumque brevibus uni- vel raro bi-seriatis; filis primariis usque ad 500 μ crassis, flexuosis, apicibus plerumque abruptis, sed interdum in cellula singula terminatis, cellulis saepe in seriebus longitudinalibus distinctis, interdum leviter spiralibus, dispositis, sed in filis latissimis subirregulariter ordinatis; cellulis non elongatis formae variabilis, in filis latissimis cytioplasmate saepe in membranam exteriorem incrassatam papilliforme porrecto, pyrenoidibus 1–2; discus adhaerens flabelliformis e seriebus arctis radiantibus cellularum angustarum constans.

Lat. fil. prim., 45–500 μ: lat. ram. 1–2 seriat., 15–18 μ; crass., cell., 7–12 μ.

Samples 323, 325, 330.

This species appears to occur not uncommonly in the brackish water near the mouths of the rivers in Kentani. None of the thalli in the three samples reached any considerable dimensions, but some at least seemed to present the mature condition. *E. basiramosa* therefore belongs to the *Entero-*

morphas of small stature, such as *E. minima*, Naeg., *E. aureola* (Ag.), Kuetz., and *E. fucicola* (Menegh.), Kuetz.

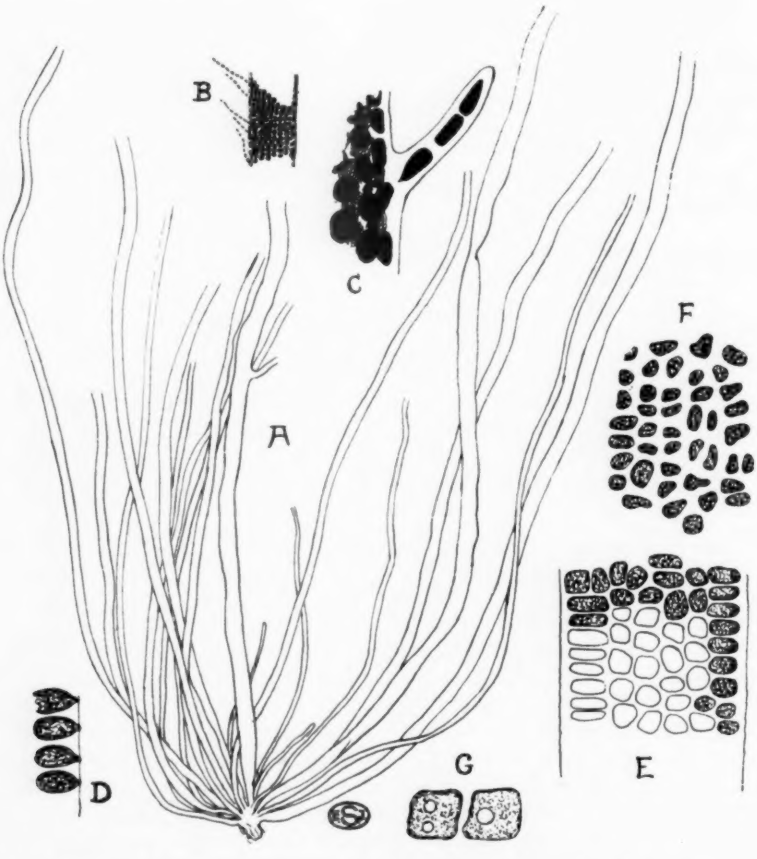


FIG. 4.—*Enteromorpha basiramosa*, F. E. Fritsch, n. sp. *A*, single thallus, enlarged about twenty times. *B*, part of the upper portion of one of the primary filaments, showing the small uniseriate branches. *C*, small part of the same on a larger scale. *D*, cells, seen in optical section, from the margin of one of the wider filaments, showing the papilla-like protrusion of the protoplasm into the thickened outer wall. *E*, and *F*, parts of older filaments showing the disposition of the cells. *G*, single cells. *B* × 100; *C–F* × 450; *G* × 700.

The most marked characteristic of the new species lies in the abundant branching that takes place just above the base of the plant (Fig. 4, *A*, and

Fig. 5). The lower part of the thallus of a mature specimen is a broad structure passing over gradually, on the one hand into the fan-shaped attaching organ (Fig. 5), and on the other hand into the numerous branches that arise just above the base (Figs. 4, *A*, and 5). The organ of attachment is composed of closely apposed, more or less radiating rows of rather narrow and elongated cells (Fig. 5). The cells in the thallus proper are never markedly elongated, but apart from that vary much in shape. In part they are approximately isodiametric, as seen from the surface, in part somewhat drawn out in the transverse or longitudinal direction (Fig. 4, *E*–*G*). In optical section, at the edge of the thallus, they either appear elongated at

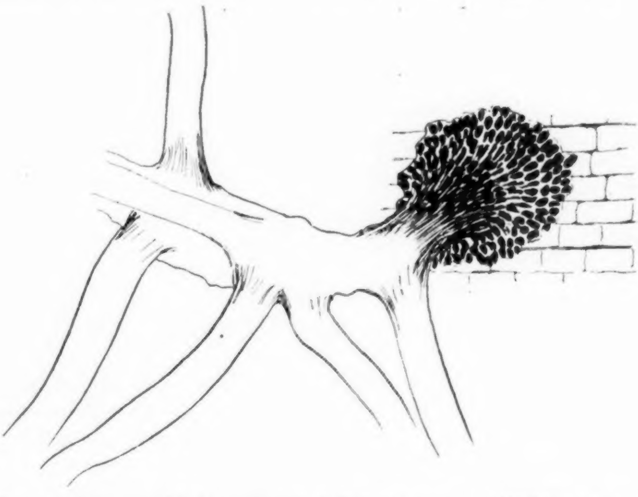


Fig. 5.—*Enteromorpha basiramosa*, F. E. Fritsch, n. sp. Attaching base and lower portion of a mature thallus. × 40.

right angles to the surface or somewhat flattened. As shown in Fig. 4, *E* and *F*, the shape of the cells may vary appreciably, even in small parts of a thallus. In the vast majority of cases the cells are arranged in very obvious longitudinal rows (Fig. 4, *B* and *E*), which were sometimes observed to have a slight spiral trend. In the broadest filaments, however, this regular disposition, though still recognisable, may become somewhat obscured (Fig. 4, *F*). The outer wall of the cells is markedly thickened—more so than the side walls (Fig. 4, *E*). Especially in the wider threads, the protoplast appears not uncommonly to protrude in a papillate manner into the thickened outer wall (Fig. 4, *D*). The cells have one or two pyrenoids (Fig. 4, *G*).

Apart from the abundant branching just above the base, the production of larger branches in the upper part of the thallus is rare (*cf.* Fig. 4, *A*).

2

At certain points, however, there occur numerous fine branches composed of one, or more rarely of two, rows of cells (Fig. 4, *B*, *C*). These branches are quite short, run to a point, and do not branch further. They are very erratic in their occurrence, whole areas of the thalli being completely devoid of them. The large main branches of the thallus were almost invariably broken off or dead at the tips (Fig. 4, *A*), but when the actual end was present it was always pointed, the branch terminating in a single cell. The main filaments gradually widen to a slight extent from the base upwards, but retain a rather even edge (Fig. 4, *A*); in a few cases the distal end was irregular in shape.

(6) CLADOPHORACEAE.

Genus RHIZOCLONIUM Kuetzing.

1. *Rhizoclonium hieroglyphicum* (Kuetz.), Stockmayer, Ueb. d. Algengatt. *Rhizoclonium*, Verh. k. k. Zool.-Bot. Ges. Wien, xl, 1890, p. 578; Kuetzing, Phyc. germ., 1845, p. 206.

Sample 329 (common).

Previously recorded from South Africa (Wille) and Cape Colony (Fritsch).

Genus CLADOPHORA Kuetzing.

1. *Cladophora glomerata* (L.), Kuetzing, Phyc. germ., 1845, p. 212.

Sample 79.

A form in which the membrane of the cells was provided with distinct longitudinal folds. Very faint striolations were also often recognisable, so that there is some resemblance to var. *ornata*, Lemmermann ('Forschungsber. Biol. Stat. Ploen,' 1895, sep. copy, p. 35, fig. 8), in which, however, the striae more pronounced.

Previously recorded from Orange Free State (Fritsch).

(Note.—Undeterminable material of this genus was also present in samples 323, 325, and 329.)

(*f*) CHAETOPHORALES.

(1) CHAETOPHORACEAE.

Genus STIGEOCLONIUM Kuetz (MYXONEMA Fries).

1. *Stigeoclonium falklandicum*, Kuetzing, Tab. Phyc., III, 1853, t. 2.

Samples 70 (?), 71 (?).

A form showing a certain amount of constriction between the cells, but otherwise agreeing with the diagnosis of this little-known species. Most of

the cells were not more than two or three times as long as broad. *Myxonema attenuatum*, Hazen ('Mem. Torrey Bot. Club,' xi, 1902, p. 206, pl. xxxv) comes very close to the form in question, except as regards the constriction between the cells, and it may be doubted if it is more than a variety of *S. falklandicum*.

(2) CHAETOSPHAERIDIACEAE.

Genus CHAETOSPHAERIDIUM Klebahn.

1. *Chaetosphaeridium globosum* (Nordst.), Klebahn, Pringsh. Jahrb., xxv, 1893, p. 306, Tab. XIV, figs. 5–10. (Syn.: *Herposteiron globosa*, Nordst.; *Aphanochaete globosa*, Wolle.)

Samples 311, 312.

Previously recorded from Cape Colony (Fritsch).

(4) COLEOCHAETACEAE.

Genus COLEOCHAETE Brébisson.

1. *Coleochaete scutata*, Brébisson, Ann. sci. nat., sér. 3, Bot., i, 1844, p. 29, Pl. II, figs. 1–7.

Sample 327 (on fragments of leaves and on the filaments of *Spirogyra bellis* (Hass.), Cleve.)

Previously recorded from Cape Colony and Orange Free State (Fritsch).

2. *Coleochaete orbicularis*, Pringsheim, Beitr. z. Morph. u. Syst. d. Algen, iii, Pringsh. Jahrb., ii, 1860, p. 11, Pl. I, fig. 5, etc.

Sample 343 (on dead leaves).

(*g*) OEDOGONIALES.

(1) OEDOGONIACEAE.

Genus OEDOGONIUM Link.

1. *Oedogonium pusillum*, Kirchn.; Hirn, Monogr. u. Iconogr. d. Oedogoniaceen, 1900, p. 299, Tab. XXIV, fig. 125. (Syn.: *O. africanum*, Lagerh.; *O. klebahnii*, Lemm.)

Forma paullo major, lat. cell. veg., 6–7·5 μ; lat. oogon., 20–21 μ; long. oogon., 27–33 μ.

Sample 36.

In view of the scanty nature of the material and of the absence of ripe oospores, the reference of this form to *O. pusillum* is somewhat doubtful. Except for the larger dimensions, however, all the characters agreed with the diagnosis in Hirn. The oogonia were biconical-ellipsoid, with a wide median operculum, and the basal cell was hemispherical. Neither antheridia nor dwarf males were encountered, so that the present observations support the view that this species is dioecious and macrandrous. *O. pusillum* has been recorded from Abyssinia by Lagerheim.

2. *Oedogonium pringsheimii*, Cramer; Hirn, *op. cit.*, p. 170, Tab. XXVII, fig. 155.

Sample 159.

Diam. cell. veg., 15 μ, altit. usque 4–5-plo major; diam. oogon., 39 μ.

Previously recorded from Little Namaqualand (G. S. West).

3. *Oedogonium* sp. (*O. varians*, Wittr. et Lund.; Hirn, *op. cit.*, p. 89, forma ?).

Samples 311, 312.

Only sterile filaments and such as bore oogonia were observed. The form thus appears to be dioecious—a condition which is not unknown in *O. varians* (*cf.* Hirn, p. 90). The oogonia were often pyriform, but in a few cases the shape was more elliptical; there was an almost superior pore which was generally difficult to recognise. The basal cell was hemispherical which is not the type hitherto recorded for *O. varians*. The dimensions were: Lat. cell. veg., 7–9 μ, long., 27–50 μ; lat. oogon., 22–27 μ, long., 24–30 μ.

(Note.—Sterile species of *Oedogonium* were also observed in samples 17, 19, 20, 21, 29, 86, 327, 329, 330, 331, 334, 340, 341, and 342.)

Genus BULBOCHAETE Agardh.

(Note.—Only sterile material of this genus was present, viz. in samples 86, 159, 311, 339, and 340.)

(*h*) SIPHONALES.

(2) VAUCHERIACEAE.

Genus VAUCHERIA De Candolle.

1. *Vaucheria sessilis* (Vauch.). De Candolle; Heering, Suesswasseralg. Schleswig-Holsteins, etc., ii, Jahrb. d. Hamburg. Wiss. Anst., xxiv, 1906, p. 143.

Sample 344 (f. *repens*, Rabenh.).

(Note.—Sterile material of this genus was encountered in samples 24, 66, and 334.)

(*i*) CONJUGATAE.

(1) MESOTAENIACEAE.

Genus CYLINDROCYSTIS Menegh.

1. *Cylindrocystis brebissonii*, Menegh.; W. & G. S. West, Monogr. Brit. Desm., i, Ray Society, 1904, p. 58, Pl. IV, figs. 23–32.

Sample 36.

Long., 51 μ; lat., 17 μ.

Var. *minor*, W. & G. S. West, *loc. cit.*, p. 59, Pl. V, fig. 11.

Sample 36.

Long., 36 μ; lat., 12 μ.

(2) DESMIDIACEAE.

Genus PENIUM Brébisson.

1. *Penium margaritaceum* (Ehrenb.), Bréb.; W. & G. S. West, *loc. cit.*, p. 83, Pl. VIII, figs. 32–35.

Var. *irregularius*, W. & G. S. West, Freshw. Alg. Orkneys and Shetlands, Trans. and Proc. Bot. Soc. Edinburgh, xxiii, 1905, pp. 14, 15, fig. 23 (fig. *nostr.* 6, *C*).

Sample 327 (not uncommon).

Long. cell., 141–204 μ; lat., 22–25 μ. This form has already been recorded by F. E. Fritsch from the Cape, whilst the type is known from Madagascar. The specimens in the present sample were rather larger, but still appreciably smaller than those originally described by Messrs. West from the Orkneys and Shetlands. Another difference lies in the small size of the granules (Fig. 6, *C*).

2. *Penium minutum* (Ralfs), Cleve; W. & G. S. West, *loc. cit.*, p. 83, Pl. X, figs. 1, 2.

Var. *productum*, F. E. Fritsch, nov. var. (Fig. 6, *D*).

P. multo brevior et paullo latior quam typo; cellulis in media parte constrictione exigua late aperta praeditis et paullo ante polos rotundato-truncatos levissime constrictis; membrana glabra, hyalina. Long., 63–65 μ; lat., 18–20 μ.

Sample 36 (rare).

This variety comes near to var. *tumidum*, Wille (*cf.* W. & G. S. West, *loc. cit.*, p. 104, Pl. X, fig. 5), in which, however, the median constriction is more pronounced and the subapical contraction is absent; the latter feature gives the ends of the cells of var. *productum* a protruded appearance. The sides of the semi-cells, however, in both cases converge towards the ends, so that the greatest width is a little way above the base. Borge ("Alg. erst. Regnellschen Exped., ii, Desmid.," 'Arkiv. f. Bot.,' i, 1903, Tab. I, fig. 4) has figured specimens of this species under the name of var. *crassum*, West in

which there is also a slight convergence of the sides which are not parallel, as in the typical var. *crassum*. These specimens seems to link up vars. *crassum* and *tumidum*.

Genus CLOSTERIUM Nitzsch.

1. *Closterium pegleri*, F. E. Fritsch, n. sp. (Fig. 6, *B*).

C. submediocre; cellulis singulis vel saepe in fasciculos e cellulis numerosis compositos consociatis, semilunaribus, lanceolatis, medio paullo

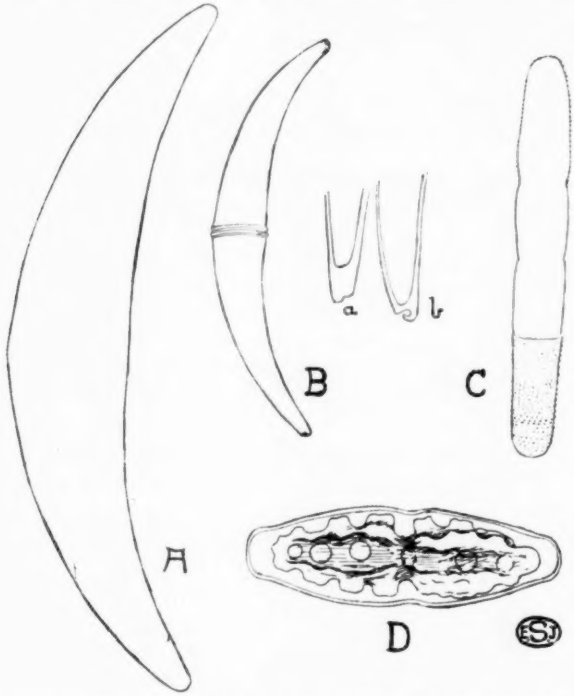


Fig. 6.—*A*, *Closterium ehrenbergii*, Menegh., var. *concavum*, Schmidle, forma. *B*, *C. pegleri*, F. E. Fritsch, n. sp. *a* and *b*, the ends of two cells enlarged. *C*, *Penium margaritaceum* (Ehrenb.), Bréb., var. *irregularius*, W. & G. S. West. *D*, *P. minutum* (Ralfs), Cleve, var. *productum*, F. E. Fritsch, nov. var. *A* × 225; *B* and *C* × 375; *a*, *b* and *D* × 750.

inflatis, polos versus magis curvatis et sensim attenuatis; apicibus incrassatis, oblique truncatis, et illic laterem dorsalem versus plus minus profunde excavatis; membrana glabra rubra vel rubiginosa; suturis medianis 1–6; cellulis granulis amylaceis magnis repletis, ita ut chromatophora et pyrenoides (in serie axiali?) obscurantur. Dist. inter apic., 195–210 μ; lat. med., 24–25 μ.

Samples 158 (common), 159 (rare).

The individuals of this species, named after the collector, usually occurred in more or less extensive groups comprising any number of cells up to 50, arranged approximately parallel to one another and in close juxtaposition. The general shape of the cell (Fig. 6, *B*) is not unlike that of *C. leibleinii*, Kuetz., but the ends are altogether different, being obliquely truncated, more or less markedly thickened, and provided with a characteristic excavation of the membrane of varying depth (Fig. 6, *a*, *b*). The cell-wall, although apparently colourless when first secreted, very soon takes on a reddish or brownish-red tinge; in a few cases it showed a very fine granulation. The cells are provided with a varying number of median sutures (Fig. 6, *B*). The contents invariably included a large number of big starch grains, which made it impossible to decipher the chloroplast; a single axial series of pyrenoids, however, seems to be present.

There is some resemblance between this species and *C. excavatum*, Borge ("Suesswasseralg. aus Suedpatagonien," 'Bih. K. Sv. Vet.-Akad. Handl.,' xxvii, Afd. III, No. 10, 1901, p. 19, Tab. II, figs. 7–9); in the latter, however, the ends are different, the membrane is apparently colourless, and there are no median sutures.

2. *Closterium parvulum*, Naegeli, Gatt. einzell. Algen., 1849, p. 106, Tab. VI, C, fig. 2; W. & G. S. West, *loc. cit.*, p. 133, Pl. XV, figs. 9–12.

Samples 36, 338, 339, 340.

Dist. inter apic., 112–135 μ; lat., 11–13 μ.

Previously recorded from Cape Colony (Fritsch).

var. *angustum*, W. & G. S. West, *loc. cit.*, p. 134, Pl. XV, figs. 13, 14.

Samples 338, 339, 340.

Dist. inter apic., 93–96 μ; lat., 6 μ.

3. *Closterium leibleinii*, Kuetz.; W. & G. S. West, *loc. cit.*, p. 141, Pl. XVI, figs. 9–14.

Sample 315.

Long., 208 μ; lat., 35 μ.

Previously recorded from Little Namaqualand (G. S. West), from Madagascar (Fritsch), and Cape Colony and Orange Free State (Fritsch).

4. *Closterium moniliferum* (Bory), Ehrenb.; W. & G. S. West, *loc. cit.*, p. 142, Pl. XVI, figs. 15, 16.

Samples 26, 35, 64, 65, 85, 312, 327, 334, 336, 337.

Previously recorded from Little Namaqualand (G. S. West) and Cape Colony (Fritsch).

5. *Closterium ehrenbergii*, Menegh.; W. & G. S. West, *loc. cit.*, p. 143, Pl. XVII, figs. 1–4.

Samples 17, 18, 23, 329 (?), 334.

Previously recorded from Little Namaqualand (G. S. West).

Var. *concavum*, Schmidle, Suesswasseralg., in F. Reinecke, Flora d, Samoa-Inseln, Engler's Bot. Jahrb., xxiii, 1897, p. 256.

Forma major, margine ventrali in media parte cellulae fere recta. Long. cell., 520–570 μ; lat., 90–102 μ (Fig. 6, *A*).

Sample 327.

6. *Closterium acerosum* (Schrank), Ehrenb.; W. & G. S. West, *loc. cit.*, p. 146, Pl. XVIII, figs. 2–5.

Samples 22, 23, 334.

Long., 330–405 μ; lat., 34–40 μ.

Previously recorded from South Africa (G. S. West & Fritsch).

7. *Closterium lanceolatum*, Kuetz.; W. & G. S. West, *loc. cit.*, p. 149, Pl. XVII, figs. 9, 10, Pl. XVIII, fig. 7.

Samples 17, 23, 334, 336.

Long. cell., 387–405 μ; lat., 57–66 μ.

Recorded from Madagascar (Fritsch), the Karoo and Little Namaqualand (G. S. West).

8. *Closterium pritchardianum*, Arch.; W. & G. S. West, *loc. cit.*, p. 172, Pl. XXII, figs. 6–14.

Forma ad var. *alpinum*, Schmidle (Oesterr. Bot. Zeitschr., xlv, 1895, p. 309, Pl. XIV, fig. 19) valde accedens, sed saepe longior et latior, membrana paene achroa et subtilissime striata, apicibus plerumque magis recurvis quam in specimine a Schmidle depicto. Dimens., 360 × 45, 420 × 54, 555 × 40, 660 × 45 μ.

Samples 85, 346 (very rare in the latter).

This form has to some extent the subparallel margins of var. *madagascariense*, Fritsch. The work already done on the freshwater Algae of South Africa shows that *C. pritchardianum* is very widely distributed and exhibits very considerable variability (*cf.* Fritsch, 1918, p. 547). It is hoped at a later date, when more data have been collected, to give an epitome of the different forms.

9. *Closterium pseudolibellula*, F. E. Fritsch, n. sp. (Fig. 7).

C. magnum; cellulis aut fusiformibus margine ventrali minus convexa quam margine dorsali (forma *fusiformis*) aut saepe margine dorsali valde convexa margine ventrali deplanata vel (raro) exigue concava (forma *genuina*), a media parte ad polos gradatim et magis attenuatis; polis truncatis et recurvis (qua nota in speciminibus biconvexis saepe indistincta val abest); membrana primum achroa, mox flavescens, in tota superficie punctis minutis numerosis irregulariter ordinatis obtecta; chromatophora e

ca. 10 laminis formata, pyrenoidibus magnis 3–5 in serie axiali in quaque semicellula. Dimens., 351 × 57, 354 × 54, 378 × 55, 390 × 60, 400 × 55. 405 × 60, 420 × 57 μ; lat. apic., 6 μ.

Sample 346 (common).

This rather distinct species occurs in two forms, the one (f. *fusiformis*) showing a marked superficial resemblance to *C. libellula*, Focke, the other (f. *genuina*) somewhat resembling a stout specimen of *C. pritchardianum* Arch.; the latter form is the more common.

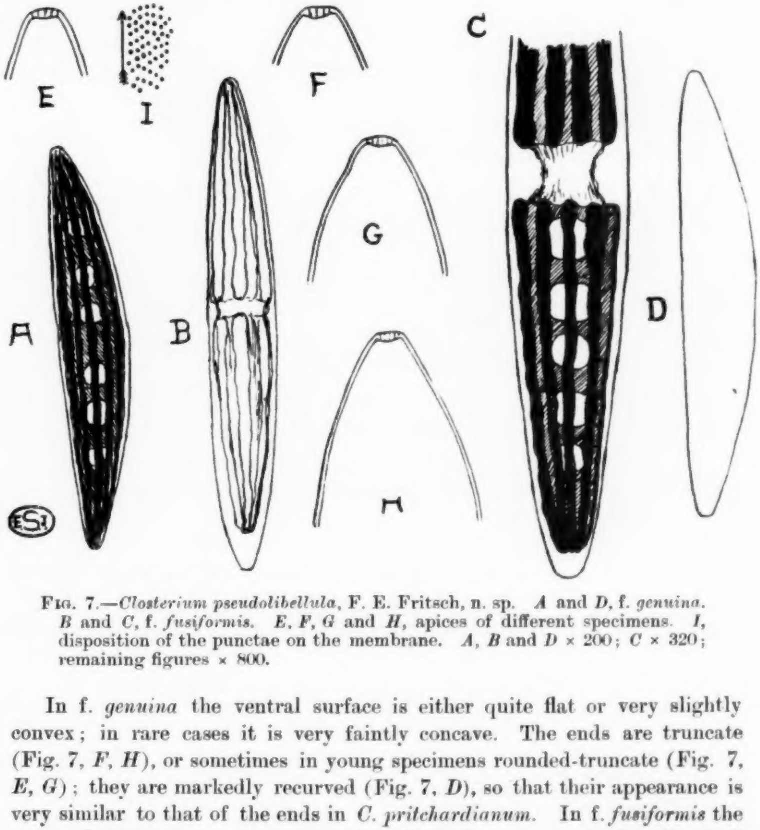


FIG. 7.—*Closterium pseudolibellula*, F. E. Fritsch, n. sp. *A* and *D*, f. *genuina*. *B* and *C*, f. *fusiformis*. *E*, *F*, *G* and *H*, apices of different specimens. *I*, disposition of the punctae on the membrane. *A*, *B* and *D* × 200; *C* × 320; remaining figures × 800.

In f. *genuina* the ventral surface is either quite flat or very slightly convex; in rare cases it is very faintly concave. The ends are truncate (Fig. 7, *F*, *H*), or sometimes in young specimens rounded-truncate (Fig. 7, *E*, *G*); they are markedly recurved (Fig. 7, *D*), so that their appearance is very similar to that of the ends in *C. pritchardianum*. In f. *fusiformis* the recurved character is only very faintly indicated as a general rule (Fig. 7, *B* and *G*)—in fact in some individuals it is altogether indiscernible. A marked characteristic of the species lies in the fact that the membrane very soon takes on a yellowish or yellowish-brown tinge, and that the entire

surface bears a punctation which appears to be due to very numerous minute pits in the wall (*cf.* Fig. 7, *E–H*). The pits are quite irregularly arranged over all parts of the cell. The colouration of the membrane is in general rather faint. The protoplasmic contents were often highly vacuolate.

In shape f. *genuina* is not unlike some forms of *C. spetsbergense*, Borge ('Vid.-selsk. Skrift., Kristiania, I, Mat.-nat. Kl.,' 1911, No. 11, p. 8, fig. 5 *a*); this species is, however, considerably smaller and has a colourless glabrous membrane. Comparison may also be made with *C. massarti*, De Wildeman, *C. fusiforme*, Gay, and *C. methueni*, Fritsch.

10. *Closterium rostratum*, Ehrenb., W. & G. S. West, *loc. cit.*, p. 188, Pl. XXVI, figs. 1–5.

Samples 338 and 339 (in both cases with zygospores), 340.

Recorded from Madagascar (Fritsch).

Genus PLEUROTAENIUM Naegeli.

1. *Pleurotaenium ehrenbergii* (Bréb.), De Bary, Unters. ueb. d. Fam. d. Conjug., 1858, p. 75; W. & G. S. West, *loc. cit.*, p. 205, Pl. XXIX, figs. 9–11.

Samples 26, 327 (in the latter not uncommon).

Previously recorded from the Cape (Nordstedt and Fritsch).

2. *Pleurotaenium ovatum*, Nordstedt, Alg. aq. dulc. Brasil., Oefvers. K. Sv. Vet.-Akad. Foerhandl., 1877, No. 3, p. 18. (Syn.: *Docidium ovatum*, Nordst., Vid. Med. Nat. Foren. Kjobenhavn, 1869, p. 205, Tab. III, fig. 37.)

Sample 327.

Long. cell., 270–340 μ; lat. max., 81–87 μ; lat. constr., 45–60 μ; lat. apic., 25–27 μ. These dimensions are appreciably less than those originally recorded by Nordstedt. Slightly smaller specimens have been described by Schmidle (Engler's 'Bot. Jahrb.,' xxvi, 1899, p. 23) as var. *minor*, but it is doubtful if this variety can be retained, since the size of the species is subject to much fluctuation.

The specimens in sample 327, while showing the typical shape, exhibited the annular thickening at the constriction figured by W. & G. S. West for var. *tumidum*, Maskell ('Ann. Roy. Bot. Garden, Calcutta,' vi, Part II, 1907, Pl. XIII, fig. 8) and by Turner for his *Docidium rotundatum* ('Sv. Vet.-Akad. Handl.,' xxv, No. 5, 1892, t. vii, fig. 2 *a*), which is probably synonymous with the former. They also differed in the fact that the membrane appeared to be not punctate, but delicately and irregularly striate.

This species has been recorded from the Cape by Nordstedt and Fritsch.

GENUS EUASTRUM EHRENBERG.

1. *Euastrum submontanum*, F. E. Fritsch, n. sp. (Fig. 8).

E. parvum, circiter 1½plo longius quam latum, profunde constrictum sinu subangusto-lineari extus gradatim ampliato. Semicellulae obscure trilobae, sinu late aperto inter lobos; lobo polari lato, apice deplanato vel raro leniter convexo, incisura mediana subprofunda extus ampliata, cum granulis 2 in utroque latere incisurae, angulis apicalibus dente parvo munitis, marginibus lateralibus lobi polaris subparallelis; lobis lateralibus bilobulatis, iis superioribus rotundatis vel subtruncatis vel dente parvo munitis, iis inferioribus late rotundatis; semicellulis plerumque granulis ca. 4 intra lobum lateralem utrumque et granulis 5–6 intra angulum apicalem utrumque, membrana in media parte glabra. A latere visae elongato-ovatae

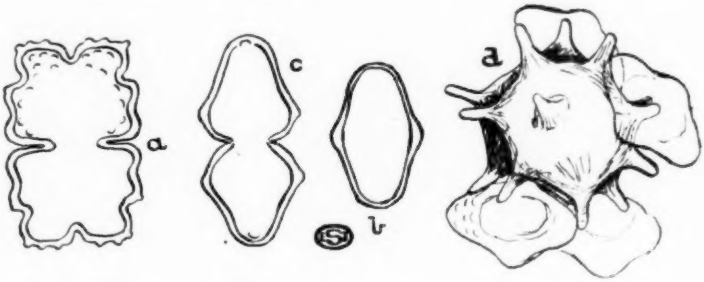


FIG. 8.—*Euastrum submontanum*, F. E. Fritsch, n. sp. *a*, front-, *c*, side-, and *b*, end-views. *d*, zygospore with the four semi-cells of the two conjugating individuals. × 1000.

apice rotundato dente parvo munito, tumore distincto prope basin utrobique. A vertice visae ellipticae, polis rotundatis, inflatione mediana (ubi membrana incrassata) distincta. Zygosporis globosis processibus crassis basi auctis ca. 15 munitis.

Long. cell., 29–31 μ; lat. cell., 19–22 μ; lat. lob. pol., 15–17 μ; lat. isthm., 6–7 μ; crass., 14–16 μ; lat. zygosp. sine proc., 20–21 μ; long. proc. zygosp., 5–7 μ.

Sample 36 (rather rare).

This species shows considerable resemblance to *E. montanum*, W. & G. S. West, especially as regards the side- and end-views. The front-view is, however, rather different. The zygospore of *E. montanum*, which has been figured by Luetkemueller ("Desm. Boehmens," 'Verh. k. k. zool.-bot. Ges. Wien,' 1910, p. 483, fig. 2), also differs from that of *E. submontanum*, having more numerous and falcate processes.

2. *Euastrum simpliciforme*, F. E. Fritsch, n. sp. (Fig. 9).

E. subparvum, circiter 2plo longius quam latum, subprofunde constrictum sinu subangusto-lineari extus paullo ampliato. Semicellulae trapeziformes, apice leniter concavo vel interdum triundulato, lateribus leniter convergentibus tricrenatis (angulis apicalibus inclusis), crenis superioribus prope apice, crenis inferioribus ca. in media parte marginis lateralis; angulis basalibus subrectangulari-rotundatis. Membrana in tota superficie semicellulae glabra. A latere visae ellipticae, apice subrotundato, intra marginem lateralem lineis duabus cum crenis lateralibus

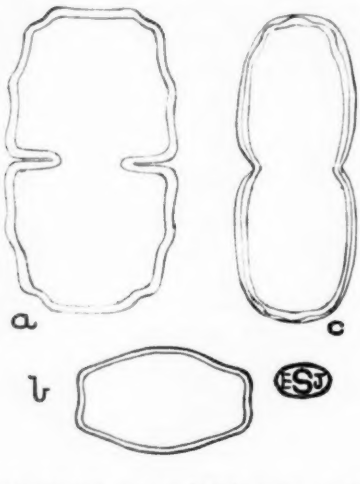


FIG. 9.—*Euastrum simpliciforme*, F. E. Fritsch, n. sp. *a*, front-, *b*, end-, and *c*, side-views. × 1100.

in aspectu frontale congruentibus. A vertice visae subellipticae, polis deplanatis retusis, inflatione mediana subdistincta.

Long. cell., 40–42 μ; lat. cell., 21–24 μ; lat. isthm., 9 μ; crass., 15–16 μ.

Sample 327 (very rare).

This species might almost equally well be regarded as belonging to the genus *Cosmarium*, the chief reasons for referring it to *Euastrum* lying in the character of the side-view and the usual concavity of the apex of the semi-cell. As a matter of fact it shows considerable resemblance to *Cosmarium angulatum*, Perty, a species which is not at all well known. It differs from the latter in having a narrower isthmus and in the character of the lateral margins; the end-view, which is not known in the case of *Cosmarium angulatum*, also appears distinctive.

GENUS COSMARIUM CORDA.

1. *Cosmarium pachydermum*, Lundell, Desm. Suec., 1871, p. 39, Tab. II, fig. 15; W. & G. S. West, *op. cit.*, II, 1905, p. 139, Pl. LVII, fig. 7.

var. *tuberculatum*, F. E. Fritsch, nov. var. (Fig. 10).

Cellulis ca. $1\frac{1}{2}$plo longioribus quam latis, a latere visis lateribus minus convexis apicibus minus rotundatis et cum membrana incrassata; semicellulis cum tuberculo late rotundato infra apicem utrobique e excavatione vadosa orto.

Long. cell., 70–90 μ; lat. cell., 48–58 μ; lat. isthm., 18–26 μ; crass., 30–36 μ.

Sample 327 (very rare).

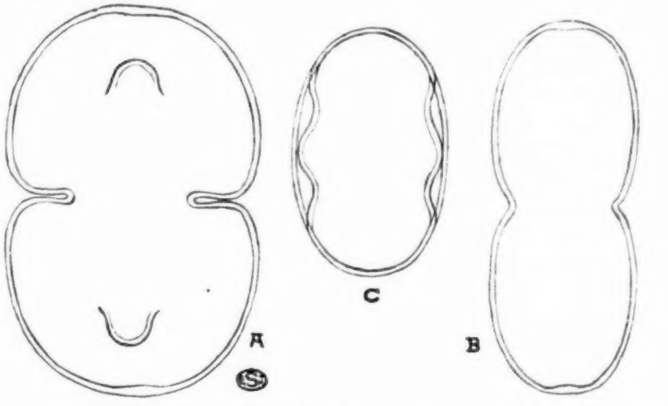


FIG. 10.—*Cosmarium pachydermum*, Lund., var. *tuberculatum*, F. E. Fritsch, nov. var. *A*, front-, *B*, side-, and *C*, end-views. × 660.

This variety differs from the type in three respects, viz. the relation between length and breadth of the cell (the semicells being more circular than elliptical), the shape of the semicells in side-view, and the broad, rounded tubercle occurring a little way beneath the apex in the median line of each semicell (Fig. 10, *A*). This tubercle arises from the base of a shallow depression,—a fact which is particularly obvious in the end-view (Fig. 10, *C*); in the front-view it only becomes distinctly visible on focussing down to about one-quarter of the thickness of the semicell. This variety, in the possession of this feature, appears to bear much the same relation to *C. pachydermum*, Lund., that *C. aitchisonii*, Schaarschmidt ("Afghanistan Algae," 'Journ. Linn. Soc., Bot.,' xxi, 1884–5, p. 246, Pl. V, fig. 20) does to *C. nitidulum*, De Not. The end- and side-views of *C. aitchisonii*, Schaarschmidt, are, however, not known, but should they

prove to resemble those of *C. nitidulum*, De Not., the former species would be better regarded as a variety of the latter.

The membrane of var. *tuberculatum* often showed a minute granulation, but its presence was not always determinable.

2. *Cosmarium undulatum*, Corda; W. & G. S. West, *loc. cit.*, p. 148, Pl. LIX, figs. 1–3, 5.

var. *crenulatum* (Naeg.), Wittr.; W. & G. West, *loc. cit.*, p. 150, Pl. LIX, figs. 11, 12. (Syn.: *Euastrum crenulatum*, Naegeli, Gatt. einzell. Alg., 1849, p. 120, Tab. VII, *A*, fig. 7.) (Fig. nostr. 11, *A*.)

Sample 327 (rare).

Long. cell., 21–22 μ; lat. cell., 16–17 μ; lat. isthm. 6 μ. The dimensions are rather less than those given in Messrs. West's monograph, but Nordstedt ('Oefvers. K. Vet.-Akad. Foerhandl.,' Stockholm, 1872, No. 6, p. 32) has already recorded specimens of this variety measuring 24 μ in length and 20 μ in breadth.

3. *Cosmarium hammeri*, Reinsch; W. & G. S. West, *loc. cit.*, p. 181, Pl. LXII, figs. 20, 21.

Sample 86 (rare).

Long. cell., 45 μ; lat. cell., 33 μ; lat. isthm., 12 μ.

var. *africanum*, F. E. Fritsch, nov. var. (Fig. 11, *B*).

C. $1\frac{1}{6}$–$1\frac{1}{3}$plo longius quam latum; semicellulae apicibus truncatis vel leniter convexis (interdum obliquis), marginibus lateralibus superioribus late concavis, marginibus lateralibus inferioribus convexo-rotundatis vel raro subangularibus, interdum subrectis; a vertice visae ellipticae, polis rotundatis, inflatione mediana distincta; a latere visae subcirculares vel elliptico-circulares. Membrana indistincte granulata.

	μ	μ	μ	μ	μ	μ
Long. cell.	27	27	27	28	30	30
Lat. cell.	21	23	24	24	24	25

Lat. isthm., 6–8 μ. Lat. apic., 10–11 μ. Crass., 15 μ.

Sample 86 (very rare), 327 (not uncommon).

This variety appears to be rather widely distributed in South Africa, as it has also been observed in samples from other parts. The reference to *C. hammeri*, Reinsch, seems correct, since in front-view there is much resemblance to var. *homalodermum* (Nordst.), W. & G. S. West, which is much bigger, and var. *protuberans*, W. & G. S. West, in which, however, to judge by the figures given by Messrs. West, the upper part of the lateral margins is not nearly so markedly concave. The new variety, however, differs from both of those just mentioned in the fact that the apex is truncate (Fig. 11, *B*, *a'*, *a''*) or even slightly convex (Fig. 11, *B*, *a*), and only very exceptionally faintly retuse; obliquity of the apex is not uncommon (Fig. 11, *B*, *a*), and, when pronounced, has a curious effect on the side-view, which then appears to bear an apical papilla. The granulation

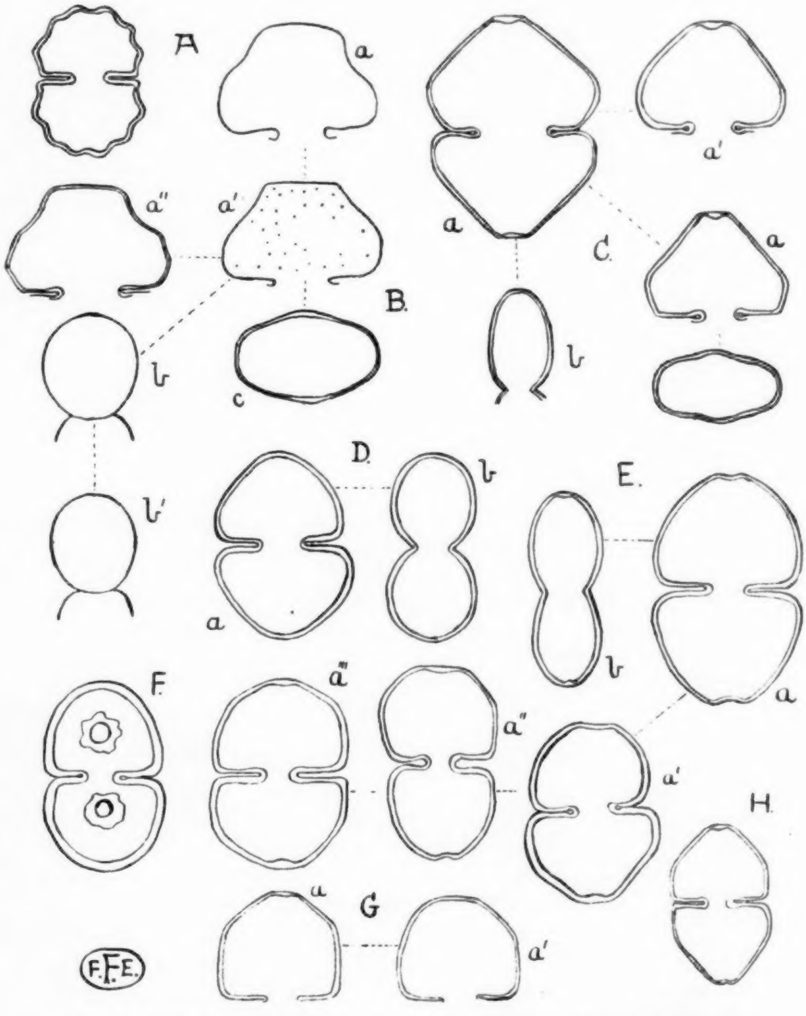


FIG. 11.—*A*, *Cosmarium undulatum*, Corda, var. *crenulatum* (Naeg.), Wittr. *B*, *C. hammeri*, Reinsch, var. *africanum*, F. E. Fritsch, nov. var. *C*, *C. granatum*, Bréb., var. *africanum*, F. E. Fritsch, nov. var. *D*, *C. laeve*, Rabenh., f. *acuminata*, n. f. *E*, *C. laeve*, Rabenh., the typical and various transitional forms. *F*, *C. laeve*, Rabenh., f. *rotundata*, n. f. *G*, *C. rectangulare*, Grun., forma. *H*, *C. granatum*, Bréb., forma. *a*, *a'*, *a''*, front-views; *b*, *b'*, side-views; *c*, end-view. All figures × 950.

of the membrane is also unusual. The median inflation in end-view (Fig. 11, *B*, *c*) is not as pronounced as is usual in the varieties of this species, and in this respect var. *africana* forms a transition to the type, which is altogether without a median inflation. The somewhat variable side-view (Fig. 11, *B*, *b*, *b'*) is also different.

It is possible that the f. *acuta* described by Turner ('K. Sv. Vet.-Akad. Hand.,' xxv, 1892, p. 53, Tab. VIII, fig. 15) belongs to this variety, A closely allied species appears to be *C. aequale*, Turner (*loc. cit.*, p. 64, Tab. IX, fig. 31).

4. *Cosmarium granatum*, Bréb.; W. & G. S. West, *loc. cit.*, p. 186, Pl. LXIII, figs. 1–3.

Samples 26, 158.

Previously recorded from Cape Colony (Fritsch).

Long. cell., 24–45 μ; lat. cell., 19–35 μ; lat. isthm., 6–8 μ.

forma apicibus leviter incrassatis vel etiam retusis.

Long. cell., 24 μ; lat. cell., 18 μ; lat. isthm., 6 μ (Fig. 11, *H*).

Sample 327 (rare).

Some specimens of this form had semicells in which the angles were more rounded than in Fig. 11, *H*, such individuals grading over into the forms of *C. laeve*, Rabenh., mentioned below.

Var. *africanum*, F. E. Fritsch, nov. var. (Fig. 11, *C*).

Semicellulis lateribus prope basin divergentibus, lateribus superioribus rectis vel levissime concavis, apicibus angustis truncatis, saepe cum membrana paullo incrassata; a latere visis lateribus minus convexis quam in typo, apicibus late rotundatis; a vertice visis ellipticis inflatione mediana distincta. Long. cell., 30–38 μ; lat. cell., 21–24 μ; lat. apic., 4–5 μ; lat. isthm., 5–10 μ; crass., 10–15 μ.

Sample 327 (rather rare).

This variety (*cf.* especially fig. 11, *C*, *a''*) seems to be near var. *subangulare*, W. & G. S. West ("Alg. Madagascar," 'Trans. Linn. Soc., Bot.,' v, 1895, p. 54, Pl. VIII, fig. 4), but the latter has retuse upper lateral margins, a retuse and rather wider apex, and a much narrower isthmus. The end-view is also quite different. There is considerable resemblance to *C. pseudogranatum*, Nordst., forma, Gutwinski ('Rozprawy Akad. Umiej. Wydz. Mat.-Przyz. Krakow,' ser. 2, xiii, 1898, p. 44, Tab. VII, fig. 38).

5. *Cosmarium pseudonitidulum*, Nordst.; W. & G. S. West, *loc. cit.*, p. 195, Pl. LXIII, fig. 26.

Var. *validum*, W. & G. S. West, *loc. cit.*, p. 196, Pl. LXIII, figs. 27–30. (Syn.: *C. pachydermum*, Lund., var. *minus*, Nordst.)

Samples 311, 312.

Long. cell., 70–72 μ; lat. cell., 55–58 μ; lat. isthm., 18–21 μ. Cell-wall thick and densely punctate.

6. *Cosmarium capense*, De Toni, Sylloge Algarum, etc., i, 1899, p. 969, (Syn.: *C. pyramidatum*, Bréb., subsp. *capense*, Nordstedt, De Alg. nonnull. praecipue Desm., etc., Act. Univ. Lund, xvi, 1880, p. 6, Tab. I, fig. 8.)

Samples 86, 158, 327.

Long. cell., 90–117 μ; lat. cell., 69–84 μ; lat. isthm., 20–24 μ; crass., 60 μ. In all cases the specimens were quite typical, the basal angles in front view being broadly rounded, the end-view broadly elliptical, and the membrane strongly punctate. This species has been recorded from the Cape by Nordstedt and Fritsch.

7. *Cosmarium obtusatum*, Schmidle, Engler's Bot. Jahrb., xxvi, 1898, p. 38; W. & G. S. West, *op. cit.*, iii, 1908, p. 7, Pl. LXV, figs. 13, 14.

Samples 311, 312 (not uncommon).

Long. cell., 60–64 μ; lat. cell., 54–57 μ; lat. isthm., 15–16 μ; crass., 21–24 μ. This species has been recorded by Schmidle from East Africa, by G. S. West from the Karoo, and by Fritsch from the Orange Free State.

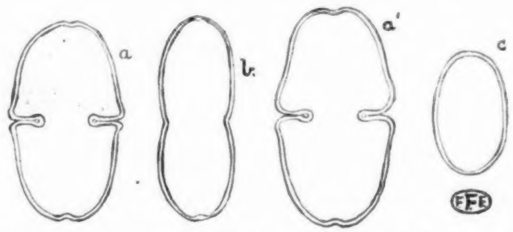


FIG. 12.—*Cosmarium quadratum*, Ralfs, var. *africanum*, F. E. Fritsch, nov. var. *a*, *a'*, front-, *b*, side-, and *c*, end-views. × 750.

8. *Cosmarium quadratum*, Ralfs; W. & G. S. West, *loc. cit.*, p. 57, Pl. LXX, figs. 6–8.

Var. *africanum*, F. E. Fritsch, nov. var. ("*forma* apice leviter retuso, membrana levissime punctata," Fritsch, Alg. Cape Peninsula, Ann. S. Afr. Mus., ix, 1918, pp. 552, 553) (Fig. 12).

Semicellulis apice leviter retusis, angulis basalibus evidenter productis lateribus convexis vel leniter concavis; a latere visis in apicem paullo incrassatis. Membrana levissime punctata. Long. cell., 39–49 μ; lat. cell., 21–25 μ; lat. isthm., 11–12 μ; crass. 14–15 μ.

Sample 36 (rather rare).

The outstanding feature of this variety is the retuse character of the apex, which is to be observed in all cases, though varying somewhat in depth. In side-view (Fig. 12, *b*) the membrane at the apex of the semicell invariably appears thickened. The punctation of the membrane is rather faint.

9. *Cosmarium regnellii*, Wille, Sydamerik. Algfl., etc., Bih. K. Sv. Vet.-

Akad. Handl., viii, No. 18, 1884, p. 16, Tab. I, fig. 34; W. & G. S. West, *loc. cit.*, p. 89, Pl. LXXII, fig. 25–28.

Forma angulis lateralibus ca. in media longitudinis semicellulae, marginibus omnibus plus minus retusis, apice lata et exigue retusa. Long. cell., 15 μ; lat. cell., 12 μ; lat. isthm., 3 μ; crass., 7 μ. (Fig. 13.)

Sample 327 (very rare).

In front-view this is very much like var. *minimum*, Eichler and Gutwinski ('Rozprawy Akad. Umiej. Wydz. Mat.-Przyr. Krakow,' ser. 2, viii, 1895, p. 164, Tab. IV, fig. 6), but this variety is described as having an end-view with a slight median inflation. There is also some resemblance with f. *minor*, Boldt, and with f. *minima* of *C. sexangulare*, Lund.; in the latter, however, the lower parts of the lateral margins are not retuse. It is to be noted that these margins differed somewhat in the specimens examined,

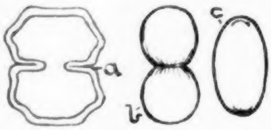


Fig. 13.—*Cosmarium regnellii*, Wille, forma. *a*, front-, *b*, side-, and *c*, end-views. × 1100.

especially as regards their degree of divergence; in some cases they were almost subparallel, and as a consequence the degree of projection of the lateral angles also varied considerably.

10. *Cosmarium meneghinii*, Bréb.; W. & G. S. West, *loc. cit.*, p. 90, Pl. LXXII, figs. 29–32.

Sample 341 (very rare).

Forma *africana*, n. f. (*forma* "marginibus lateralibus inferioribus leviter divergentibus; alioqui typo et non var. *nano*, Wille similis est," Fritsch, *loc. cit.*, p. 555). Long. cell., 18–24 μ; lat. cell., 12–15 μ; lat. isthm., 5 μ.

Samples 64, 312 (in both cases rare).

11. *Cosmarium rectangulare*, Grun.; W. & G. S. West, *loc. cit.*, p. 54, Pl. LXX, figs. 1, 2.

Forma ad var. *africanum*, W. & S. G. West ("Alg. Centr. Afr.," 'Journ. Bot.,' xxxiv, 1896, p. 379, Tab. 361, fig. 14) accedens, sed apicibus augustioribus (et raro leviter retusis), semicellulis a vertice visis ellipticis. Long. cell., 24–33 μ; lat. cell., 18–20 μ; lat. isthm., 5–6 μ. (Fig. 11, *G*.)

Sample 327 (rather rare).

These specimens approach closely to some of the forms of *C. laeve*, Rabenh., to be described below, and it is possible that they would best be regarded as extreme variations of this species. As shown in Fig. 11, *G*,

a and *a′*, the shape is somewhat variable, the angles tending to round off in some specimens. In some cases there was a slight thickening of the membrane at the apex, and as a rare feature the latter appeared very faintly retuse. The membrane was mostly, but seemingly not always, punctate. The specimens differ both from the type and from var. *africanum*, W. & G. S. West, in the very narrow apex, but even in this respect there was a certain amount of variation.

The form here described is somewhat similar to that recorded from the Cape Peninsula (Fritsch, *loc. cit.*, p. 555, fig. 28, *c*), but has, on the whole, a narrower apex. It also shows some resemblance to forms of *C. granatum*, Bréb., described by Borge ("Subfoss. soetvattensalg. fran Gotland," 'Bot. Notiser,' 1892, p. 56, and especially fig. 6).

12. *Cosmarium laeve*, Rabenhorst, Fl. Europ. Alg., iii, 1868, p. 161; W. & G. S. West, *loc. cit.*, p. 99, Pl. LXXIII, figs. 8–19.

Forma *typica*. Long. cell., 22–36 μ; lat. cell., 16–24 μ; lat. isthm., 4·5–6 μ; crass., 12 μ; lat. zygosp., 16 μ. Membrana saepe laevis. (Fig. 11, *E*, *a*, *b*.)

Samples 86, 327 (with zygospores), 345.

Previously recorded from Little Namaqualand (G. S. West).

Forma *minor* ad var. *octangularem* (Wille), W. & G. S. West accedens. Long. cell., 16 μ; lat. cell., 15 μ; lat. isthm., 3 μ.

Sample 158 (very rare).

Forma *rotundata*. Apicibus non retusis. Long. cell., 30–31 μ; lat. cell., 18–19 μ; lat. isthm., 5–6 μ. (Fig. 11, *F*.)

Sample 327 (rather rare).

Forma *acuminata*. Lateribus valde convergentibus, apicibus subrotundatis non retusis; semicellulis a latere visis lateribus plus rotundatis. Long. cell., 30 μ; lat. cell., 22 μ; lat. isthm., 6 μ; crass., 14 μ. (Fig. 11, *D*.)

Sample 327 (rare).

It is manifest that *C. laeve* is very variable in South Africa, since other forms have already been recorded from the Cape (Fritsch, 1918, p. 555). The specimens illustrated in Fig. 11, *D*, *E*, and *F*, were all drawn from the material in sample 327, but they only represent the outstanding forms, and numberless transitions between them were encountered. The typical form (Fig. 11, *E*, *a*) has retuse apices and smooth, rounded sides, the membrane in the present material being never more than obscurely punctate and in many cases seemingly quite smooth (*cf.* Fritsch, *loc. cit.*, p. 555). According to Messrs. West's monograph, "the slight retuseness in the middle of the apex is characteristic of all forms of the species," but it appears doubtful whether this statement really applies. Messrs. West ("Freshwater Chlorophyc.," in J. Schmidt, 'Fl. Koh Chang, Bot. Tidsskrift,' xxiv, 1901, Tab. II, fig. 14)

have themselves figured specimens in which the retuse apex is scarcely recognisable (*cf.* also Raciborski, 'Rozprawy Akad. Umiej. Krakow,' ser. 2. ii, 1892, Pl. VI, fig. 20, *a*), and in sample 327 forms were encountered (f. *rotundata*, Fig. 11, *F*) in which the apices were smoothly rounded off and without any trace of retuseness (side-view as in Fig. 11, *E*, *b*). Such specimens might be regarded as not belonging to *C. laeve*, were it not that they are connected with the typical form by transitions; thus, individuals were occasionally met with in which one semicell showed a retuse apex, whilst the other was rounded off as in Fig. 11, *F*. Numerous specimens were, moreover, observed in which the apex was retuse on the one semicell but merely slightly thickened on the other (Fig. 11, *E*, *a'*, *a''*). A reference to Figs. 11, *E*, *a*, *a'*, *a''*, *a'''* further shows that the shape of the semicells (either of one or both) is subject to considerable variation. Thus, the lower parts of the sides may be almost subparallel (Fig. 11, *E*, *a'*, especially the lower semicell), the sides may be somewhat angular (as in Fig. 11, *E*, *a''*), and the width of the apex rather diverse (*cf.* Fig. 11, *E*, *a*, *a'*, *a''*, etc.).

Specimens like those figured in Fig. 11, *E*, *a''*, lead over to the form of *C. rectangulare*, Grun., shown in Fig. 11, *G* (especially *a'*), whilst forms like those represented by the lower semicell in Fig. 11, *E*, *a'*, are transitional to forms of *C. granatum*, Bréb. (*cf.* Fig. 11, *H*, and p. 32).

In some few cases individuals were observed in which the sides of the semicells converged very markedly (f. *acuminata*, Fig. 11, *D*); in these the apex was not retuse, but more or less rounded, and the semicells, in side-view (Fig. 11, *D*, *b*), were more rounded than was the case with the other forms (*cf.* Fig. 11, *E*, *b*).

It would thus appear that *C. laeve*, Rabenh., may vary in respect of the apex, the punctation of the membrane, and the form of the lateral margins, extreme conditions approaching on the one hand to *C. granatum*, Bréb., on the other hand to *C. rectangulare*, Grun.

13. *Cosmarium sportella*, Bréb.; W. & G. S. West, *loc. cit.*, p. 185, Pl. LXXXII, figs. 12, 13.

var. *simplex*, F. E. Fritsch, nov. var. (Fig. 14).

Cellulis a fronte visis apice laevi, lenissime convexo vel truncato vel lenissime retuso; a vertice visis late ellipticis, inflatione mediana nulla; membrana cum granulis sparsis non punctulata, sine tumore centrali. Long. cell., 48–50 μ; lat. cell., 39–42 μ; lat. isthm., 10–12 μ; crass., 24–26 μ.

Samples 312, 314, 315.

This variety, apart from the slightly larger dimensions, differs from the type mainly in the absence of the central granulated tumour in front- and end-views. Since this tumour is developed to a very variable extent in the type itself, it is possible that no sharp limit could be drawn between it and the new variety.

14. *Cosmarium punctulatum*, Bréb.; W. & G. S. West, *loc. cit.*, p. 206, Pl. LXXXIV, figs. 13, 14.

Sample 86 (very rare).

A small form. Long. cell., 27 μ; lat. cell., 24 μ; lat. isthm., 8 μ. Previously recorded from the Cape (Reinsch, Fritsch) and Orange Free State (Fritsch).

15. *Cosmarium subcrenatum*, Hantzsch; W. & G. S. West, *loc. cit.*, p. 228, Pl. LXXXVI, figs. 10–14.

Samples 26 and 71.

Long. cell., 24–30 μ; lat. cell., 18–25 μ; lat. isthm., 7–10 μ.

Previously recorded from the Cape and Orange Free State (Fritsch).

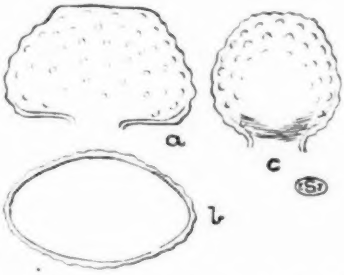


FIG. 14.—*Cosmarium sportella*, Bréb., var. *simplex*, F. E. Fritsch, nov. var. *a*, front-, *b*, end-, and *c*, side-views. × 750.

16. *Cosmarium subprotumidum*, Nordst.; W. & G. S. West, *loc. cit.*, p. 231, Pl. LXXXVI, figs. 19–21 (fig. nostr. 16, *B*).

Sample 327 (very rare).

The typical form of this Desmid was very rare in the present material, and even the few specimens observed did not altogether agree with the description and figures in Messrs. West's monograph, the basal angles in front-view being less markedly rectangular, and the tumour, though well marked, not quite so prominent in the side- and end-views. The tumour bore three rows of granules, the middle one consisting of four, the side ones of three. The dimensions were: Long. cell., 27 μ; lat. cell., 24 μ; lat. isthm., 6 μ; crass. 16 μ (Fig. 16, *B*).

It seems that this species is widely distributed in Africa and that it is subject to considerable variation. It has been recorded by Prof. West from Nyassa, Victoria Nyanza, and Tanganyika, the var. *gregorii* (Roy et Biss.), W. & G. S. West by Fritsch from the Cape and Orange Free State, whilst Schmidle has described a *Cosmarium occultum* from Lake Nyassa, which Messrs. West regard as a probable form of *C. subprotumidum*.

In sample 327 there occurred numerous *Cosmaria* diverging more or less markedly from *C. subprotumidum* proper, as described and figured for instance in Messrs. West's monograph. It has not proved possible to discriminate between these different *Cosmaria* and, although the extreme forms are sufficiently distinct from *C. subprotumidum*, they are connected with it by a whole series of transitional forms (Fig. 15). All of these forms agree to a more or less marked extent in certain respects which constitute points of difference from the typical *C. subprotumidum*. These common features are as follows.

Special granules are not developed in the central part of the semicell, although now and again slightly larger ones are found in this region. This feature is connected with a weaker differentiation of the central tumour—a fact which is very obvious in the side- and end-views (Fig. 15). In a few cases there appears to be a semicircular bare area between the marginal and central granules of the semicell, as seen in front view—an approximation to the condition found in the type—although the central granules are not larger than the others. As a rule, however, the entire semicell is uniformly granulated, the granules being arranged in more or less well-marked concentric series and often also in radiating series, although the arrangement is always more or less irregular in the centre of the semicell. In all the specimens, lastly, the apex appears smooth and truncate, an occasional appearance of undulation (as in Fig. 15, VI and VIII) being due to the presence of three to four granules just within the margin.

It may be noticed that W. West (Freshw. Alg. W. Ireland, Journ. Linn. Soc., Bot., xxix, 1891, p. 157, Pl. XXIV, fig. 21) has described a form of *C. subprotumidum* with more scattered granules and weakly differentiated central granules (*cf.* also Messrs. West's monograph, *loc. cit.*, p. 232, Pl. LXXXVI, fig. 22), and such a form helps to link up the specimens here described with the typical *C. subprotumidum*; it would be interesting to know the character of the side- and end-views of this form, since they would presumably show reduction of the central tumour. The form described by Schmidle as *C. occultum* would differ from all these in the fact that granules are altogether wanting in the middle of the semicells, and it is significant that Schmidle's rather poor figure (Engler's Bot. Jahrb., xxxii, 1902, Tab. I, fig. 25) shows a relatively slight tumour in end- and side-views.

The specimens in sample 327 that come nearest to *C. subprotumidum* are shown in Fig. 15, VIII, IX, and X (IX having the same sort of end- and side-views as VI). Such specimens are generally of rather small dimensions: long., 21–22 μ (rarely as much as 27 μ, or even 30 μ, the greatest length noted); lat., 18–19 μ (rarely up to 25 μ); lat. isthm., 5–6 μ; crass., 14–15 μ. They agree more or less with the type in the shape of the semicells (especially Fig. 15, VIII and X), in the rectangular basal angles, and in the fact that

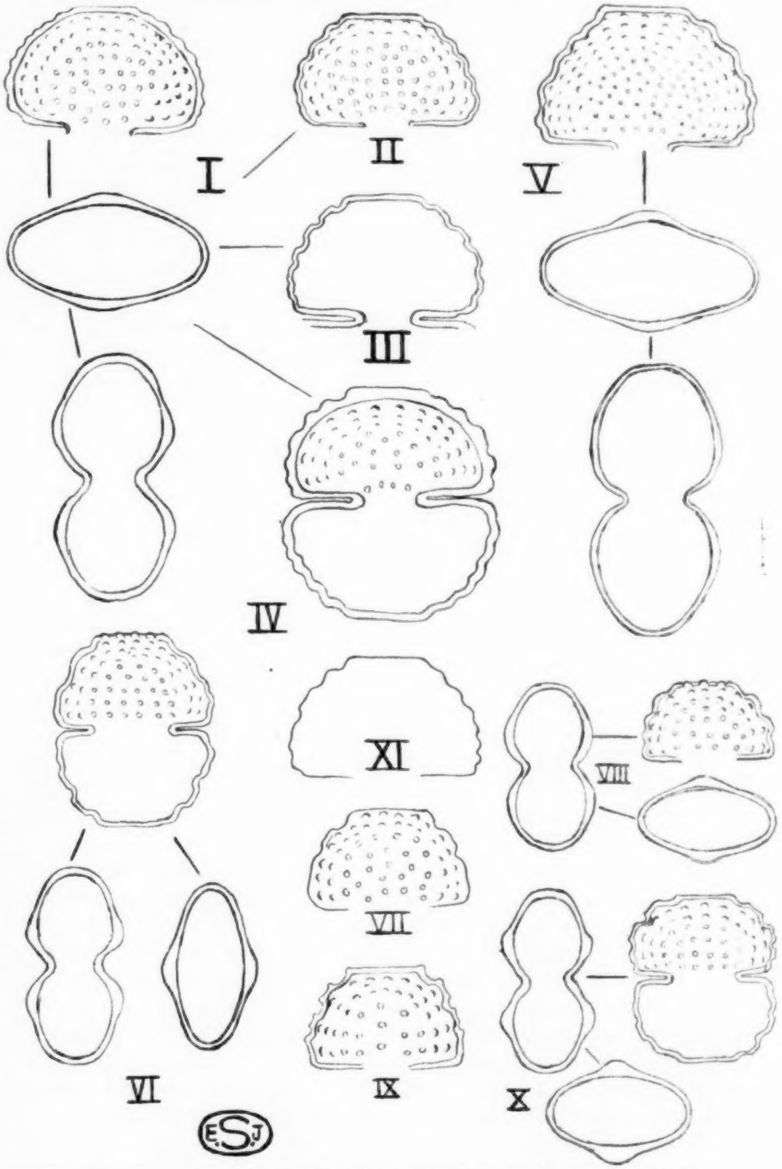


Fig. 15.—***Cosmarium subprotumidum***, Nordst., subsp. *simplex*, F. E. Fritsch, n. subsp. I, II, V, var. β. VIII–X, var. α. VI, VII, and XI, forms of var. β. III, IV, forms of var. α. × 1000.

the upper converging parts of the sides are provided with two hollows with a median crest which is retuse or even emarginate, whilst the lower parts of the sides are variously crenated. VIII is perhaps the specimen which approximates most closely in these respects, whilst X is characterised by sides which are more markedly subparallel than is usually the case, hand in hand with which appears to go the development of the tumour nearer the middle of the semicell, as seen in side-view. IX approximates somewhat towards var. *gregorii* in the bigranulate character of the crenations.

Somewhat more divergent forms are shown in Fig. 15, VII and XI; these are characterised by a rather pronounced delimitation of the apex of the semicell as a kind of square-edged apical protuberance, due to the upper hollow being deeper than usual—a feature which is also indicated in IX. VII is further distinguished by the absence of crenations on the lower parts of the lateral margins; its dimensions were: long., 25–28 μ; lat., 22 μ; lat. isthm., 6 μ; side- and end-views, as in VI. XI is characterised by a tendency towards equalisation of the crenations on the lower and upper parts of the sides (*cf.* especially the right-hand side of the semicell), although the upper ones are still larger than the lower ones.

These two specimens lead over on the one hand to that shown in Fig. 15, VI, on the other hand to those depicted in Fig. 15, I–V. The specimen VI resembles VII, except that the apex is not so sharply delimited. The median crest on the upper part of the lateral margins is still well marked though not always retuse, but the crenations on the lower parts of the sides are feeble. The dimensions were: long., 28–30 μ; lat., 24 μ; lat. isthm., 6 μ; crass., 14–15 μ. Specimens of this kind were also seen with minute granules or teeth on the lateral crenations, similar to those in Fig. 15, IX.

The forms VI, VII, and XI differ from those in Fig. 15, VIII–X, in that they tend to show a gradual convergence of the lateral margins, beginning a little way above the base of the semicell. This feature is clearly indicated in IX.

The remaining forms (Fig. 15, I–V) show this convergence to a more marked extent, and this is accompanied by an increasing equalisation of the crenations on the lateral margins (*cf.* var. *simplicius*, Schmidle, Hedwigia, xxxiv, 1895, p. 77, Tab. I, fig. 10). Specimen III is most like *C. subprotumidum*, but has two crests instead of one on the upper parts of the lateral margins; in IV and V, whilst the upper crenations are still the larger, they are rounded like the lower ones and not retuse; in II the distinction between the lower and upper crenations is but feebly indicated, whilst the extreme condition is reached in specimen I, with a very regular convergence of the lateral margins and practically uniform crenation.

These individuals, with converging lateral margins and a tendency towards uniform crenation, are the largest of the series, although connected with the smaller ones by specimen VI. Their dimensions are: long.,

30–33 μ; lat., 24–29 μ (usually 27–29 μ, only specimen II being as narrow as 24 μ); lat. isthm., 6–6·5 μ; crass., 15–18 μ. The granules of these larger specimens are more numerous and apparently somewhat smaller than those of the others, whilst the central tumour is on the average less strongly developed—in fact, in some cases it is practically unrecognisable in side-view (Fig. 15, V).

It appears that two main types are concerned, viz. (*a*) a larger one (average length, 30–33 μ), with more or less convex lateral margins gradually converging from the base of the semicell to the apex, and rather numerous lateral crenations which are equal or subequal (Fig. 15, I, II, V), and (*b*) a smaller one (average length, 21–22 μ), with the lower parts of the lateral margins subparallel, and a pronounced larger, generally retuse, crest on the upper parts of the lateral margins (Fig. 15, VII–X). Transitions to

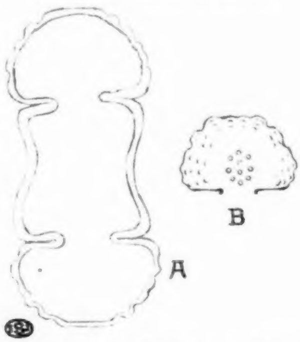


FIG. 16.—*Cosmarium subprotumidum*, Nordst. *A*. Abnormal specimen, similar to that shown in Fig. 15, II. *B*. Almost typical semicell. × 750.

type (*b*) are afforded by specimens III and IV, whilst transitions to type (*a*) are seen in VI and XI. It must be realised that there is no question of any sharp demarcation, however; if occasion had offered for the presentation of still more numerous figures, a complete series of transitions could have been shown.

It would seem to be best to include all these specimens in a subspecies *simplex*, characterised by feeble development of the central tumour, which lacks all special granulation, by uniform and generally concentric granulation of the entire semicells, and by a smooth truncate apex. I would include in this subspecies the form described by W. West (*cf.* above), and also *C. occultum*, Schmidle. Brief diagnoses are given in the following:

Cosmarium subprotumidum, Nordst., subsp. *simplex*, F. E. Fritsch, nov. subsp.: Differt a typo tumore centrali parvo sine granulis majoribus vel distincte dispositis; granulis in tota superficie semicellularum aequalibus plerumque concentricis; apicibus semicellularum planis truncatis. Long.

cell., 21–33 μ; lat. cell., 18–29 μ; lat. isthm., 5–6·5 μ; crass., 14–18 μ (Fig. 15).

var. *α*, forma minor angulis basalibus rectangularibus, marginibus lateralibus superioribus convergentibus crista mediana retusa vel etiam emarginata munitis, marginibus lateralibus inferioribus varie crenatis subparallelis. Long. cell., 21–22 μ (raro usque 27 μ, vel etiam 30 μ); lat. cell., 18–19 μ (raro usque 25 μ); lat. isthm., 5–6 μ; crass., 14–15 μ. Hac varietas ad typum appropinquat (Fig. 15, VIII–X).

Formae apicibus plus minus distincte delimitatis, crenis in parte inferiore marginium lateralium parum efformatis (Fig. 15, VI, VII, XI). Pro parte ad var. *β* accedens.

Forma, W. West, Alg. W. Ireland, 1891 (*loc. cit.*).

var. *β*, forma major marginibus lateralibus plus minus convexis, a basi ad apicem gradatim convergentibus, crenis marginium lateralium frequentioribus aequalibus vel subaequalibus. Long. cell., 30–33 μ; lat. cell., 27–29 μ (raro 24 μ); lat. isthm., 6–6·5 μ; crass., 15–18 μ. Hac varietas a typo pius discedit (Fig. 15, I, II, V).

Forma marginibus lateralibus superioribus cristis retusis vel truncatis duabus (Fig. 15, III).

Forma crenis superioribus marginium lateralium majoribus (Fig. 15, IV).

Var. *occultum* (Schmidle), 1902 (*loc. cit.*), forma minor marginibus lateralibus convergentibus, apicibus paullo protrusis leniter undulatis; marginibus lateralibus superioribus crista mediana paullo emarginata munitis; in media semicellula granulis nullis. Long. cell., 22 μ; lat. cell., 20 μ.

A curious abnormality observed among these forms of *C. subprotumidum* is shown in Fig. 16, *A*.

17. *Cosmarium calcareum*, Wittr.: W. & G. S. West, *loc. cit.*, p. 235, Pl. LXXXVII, figs. 1, 2.

Samples 311, 312, and 315.

Long. cell., 24 μ; lat. cell., 18–20 μ; lat. isthm., 6 μ.

18. *Cosmarium botrytis*, Menegh.: W. & G. S. West, *op. cit.*, iv, 1912, p. 1, Pl. XCVI, figs. 1, 2, 5–15.

Sample 159 (very rare).

Long. cell., 63–68 μ; lat. cell., 57 μ; lat. isthm., 18–21 μ.

Previously recorded from the Karoo (G. S. West), Cape Colony and Orange Free State (Fritsch).

Var. *pegleri*, F. E. Fritsch, nov. var. (Fig. 17).

Cellulis granulis majoribus frequentioribus, apicibus evidenter truncatis vel etiam retusis, a vertice visis polis subdeplanatis, a latere visis marginibus

lateralibus minus convexis. Long., 85–96 μ; lat., 66–72 μ; lat. isthm., 18–21 μ; crass., 41–42 μ.

Sample 327 (rare).

This variety is distinguished by the possession of larger and more numerous granules, by the truncate or even retuse apex, by the flattening of the poles in end-view, and the shape of the semicell in side-view. It approaches somewhat to var. *emarginatum*, Hansgirg (Prodr. Algenfl

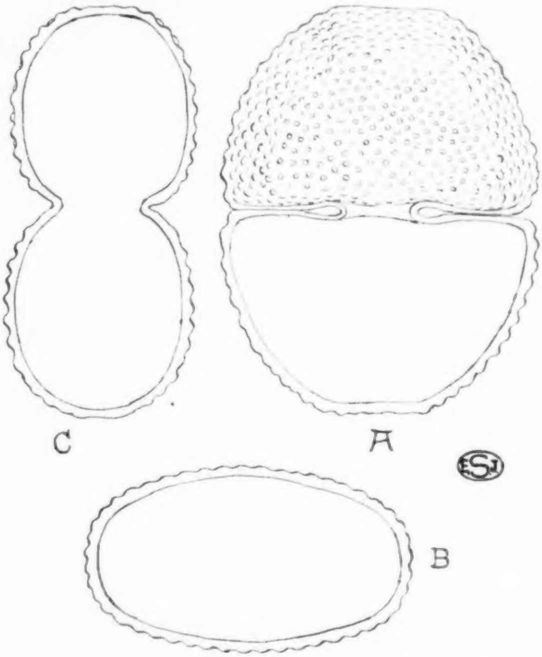


Fig. 17.—*Cosmarium botrytis*, Menegh., var. *pegleri*, F. E. Fritsch, nov. var. *A*, front-, *B*, end-, and *C*, side-views. × 660.

Boehmen, i, 1888, p. 199, fig. 116), in which, however, the apex is much narrower. There is also some resemblance to *C. deltoideum*, Delp., although end- and side-views are markedly different.

19. *Cosmarium gayanum*, De Toni; W. & G. S. West, *loc. cit.*, p. 7, Pl. CIII, figs. 5, 6.

Var. *rotundata*, F. E. Fritsch, nov. var. (Fig. 18).

Apicibus semicellularum in aspectu frontali rotundatis haud truncatis, granulis minus regulariter ordinatis, praecipue in media parte semicellularum.

Aspectus verticalis et lateralis typo similes sunt. Long. cell., 75–88 μ; lat. cell., 48–58 μ; lat. isthm., 16–18 μ; crass. 35–36 μ.

Sample 327 (very rare).

This variety is characterised by the complete rounding off of the apices of the semicells and by the more irregular arrangement of the granules, especially in the centre of the semicell. It appears to bear the same relation to the type as var. *subrotundatum*, West, does to *C. conspersum*, Ralfs. Schmidle (Alg. Carolinen, Hedwigia, xl, 1901, p. 347, Tab. XII. fig. 5) has described a var. *major* of *C. margaritatum* (Lund.), Roy et Biss., which comes rather close to this variety of *C. gayanum*.

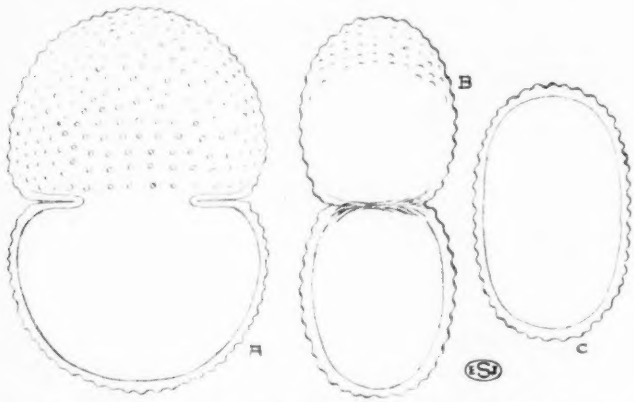


Fig. 18.—*Cosmarium gayanum*, De Toni, var. *rotundata*, F. E. Fritsch, nov. var. *A*, front-, *B*, side-, and *C*, end-views. × 660.

20. *Cosmarium quadrum*, Lund.; W. & G. S. West, *loc. cit.*, p. 20, Pl. C, figs. 3–6.

Forma paullo minor, isthmo valde incrassato, granulis saepe plus minus excavatis. Long. cell., 48–57 μ; lat. cell., 44–52 μ; lat. isthm., 15–18 μ (Fig. 19).

Samples 327, 331, and 336.

This form, as far as dimensions are concerned, comes between var. *minus*, Nordst., and the type, but it is especially distinguished by the strong thickening of the membrane at the inner edge of the isthmus, which is usually more or less triangular in shape; the thickening and longitudinal extension of this region was sometimes even more pronounced than in Fig. 19. An isthmus of a similar character is found in *C. orthopleurum*, Roy et Biss. (Journ. Bot., xv, 1886, p. 194, Tab. 269, fig. 16), which is probably but a variety of *C. quadrum*, in which, however, intergranular punctations are present. The granules in the present form were generally more or less hollow

(*cf.* var. *sublatum* (Nordst.), W. & G. S. West), although specimens were seen in which they were very nearly solid. In all other respects there was complete agreement with the type.

Var. *minus*, Nordstedt, Norges Desmid., Act. Univ. Lund, ix, 1873, No. 10, p. 11; W. & G. S. West, *loc. cit.*, p. 21.

Sample 86.

Long. cell., 48 μ; lat. 45 μ; lat. isthm., 12 μ.

21. *Cosmarium pseudobroomei*, Wolle; W. & G. S. West, *loc. cit.*, p. 22, Pl. C, figs. 7, 8.

Var. *convexum*, W. & G. S. West, *loc. cit.*, p. 23, Pl. C, fig. 9.

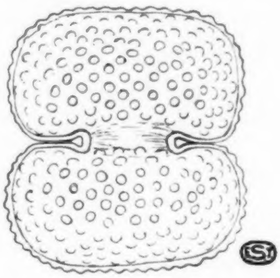


FIG. 19.—*Cosmarium quadrum*, Lund., forma. × 660.

Sample 345.

Another form of this species has been recorded from Cape Colony (Fritsch), and the type from Madagascar (Fritsch).

GENUS STAURASTRUM MEYEN.

1. *Staurastrum striolatum* (Naeg.), Arch.; W. & G. S. West, *loc. cit.*, p. 177, Pl. CXXVII, figs. 1–5.

Sample 159 (very rare).

Previously recorded from the Cape (Fritsch).

(3) ZYGNEMACEAE.

GENUS SPIROGYRA LINK.

1. *Spirogyra decimina* (Muell.), Kuetzing, Phycol. germ., 1845, p. 223; Tabul. Phycol., v, 1855, Pl. XXIII, fig. 3, Pl. XXIV, fig. 1; Petit, *Spirogyra* d. env. d. Paris, 1880, p. 25, Pl. VIII, figs. 1–3; Borge, Zygnemales, in Suesswasserfl. Deutschlands, etc., ix, 1913, p. 27, fig. 32.

f. *fuelleborni* (Schmidle), G. S. West, Journ. Linn. Soc., Bot., xxxviii, 1907, p. 106. (Syn.: *S. fuelleborni*, Schmidle, Engler's Bot. Jahrb., xxxii, 1902, p. 76, Tab. III, fig. 2).

Sample 85.

The specimens in this sample resembled Schmidle's form, particularly as regards the zygospores, which had markedly pointed ends and a yellowish-brown membrane; the dimensions were, however, rather less (lat. zygosp., 32–33 μ; long. zygosp., 50–60 μ), although exhibiting the same relative proportion between length and breadth. The vegetative filaments were 41–42 μ wide, the cells being three to six times as long as broad, and provided with three chloroplasts describing from one and a-half to two turns. The spiral bands were much broader than in Schmidle's specimens (*loc. cit.*, fig. 2, *a*), but it may be questioned whether too much stress can be laid on the width of the chloroplasts, which may well vary with local conditions of nutrition.

Schmidle compares his *S. fuelleborni* with *S. neglecta* (Hass.), Kuetz., a much wider species, with slightly inflated fructifying cells and zygospores with rounded ends. G. S. West (*loc. cit.*) regards it as a tropical form of *S. decimina*, Kuetz., a view which finds further support in the specimens just described which seem to link up *S. fuelleborni* with the typical *S. decimina*. Nevertheless it will be well for the present to maintain the form *fuelleborni*, as distinguished by the possession of three chloroplasts (always?) by the very pointed ends of the zygospores, and by the slightly different dimensions.

var. *inflata*, F. E. Fritsch, nov. var. (Fig. 20).

Var. cellulis vegetativis latioribus et diametro vulgo 2–4-plo longioribus, chromatophoris 2 anfractibus $1\frac{1}{2}$–2. Zygosporis aut fere globosis aut plus minus oblongo-ellipticis, apicibus late rotundatis raro subacutis, cellulas sporiferas non vel fere complentibus. Membrana zygosporae crassa laevis hyalina vel plus minus fusca. Cellulae fructiferae non inflatae, saepe breviores quam cellulas vegetativas. Cellulae filorum masculorum et (?) feminarum quae non conjugant semper magis inflatae.

Lat. cell. veg., 48–52 μ; long. cell. veg., 81–180 μ; lat. cell. non conjug., 69–75; lat. × long. zygosp., 49 × 75, 54 × 81, 54 × 66, 52 × 49, 51 × 87, 55 × 57, 51 × 100 μ.

Sample 316 (common).

This variety is considerably larger than the type, but it is especially distinguished by the fact that the zygospores usually have broadly rounded and not pointed ends and that the non-conjugating cells in conjugating threads are markedly inflated. This inflation has been observed more particularly in the male filaments (Fig. 20, *A*, *D*), but it would also appear to occur occasionally in the female (*cf.* Fig. 20, *I*). The filaments containing zygospores had, however, mostly dissociated into the individual

cells, and, as a consequence, it has been difficult to obtain conclusive evidence on this point. Even the thread shown in Fig. 20, *I*, is not beyond suspicion, as the second cell from the left was empty, although

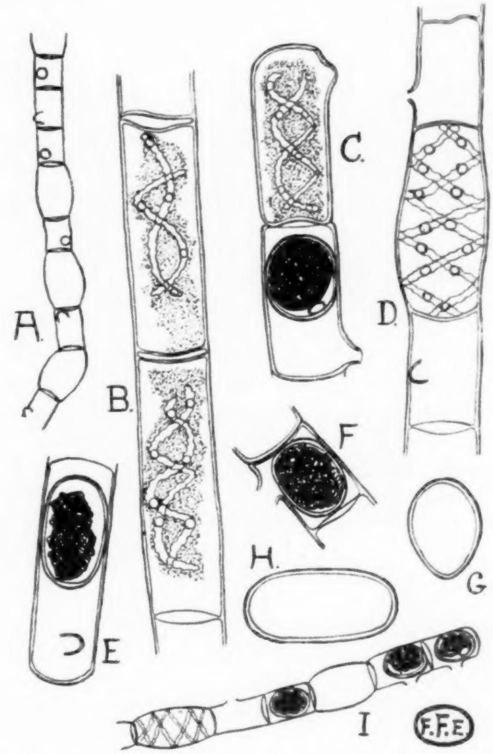


FIG. 20.—*Spirogyra decimina* (Muell.), Kuetz., var. *inflata*, F. E. Fritsch, nov. var. *A*, male thread, showing the empty conjugating cells and the inflated non-conjugating ones. *B*, two vegetative cells (the contents are shown contracted, as they appeared in the material). *C*, small part of a female thread showing an almost globular zygospore and a non-inflated vegetative cell. *D*, small part of a male thread, on a larger scale than in *A*. *E–H*, different forms of zygospores. *I*, female threads showing zygospores, a possible male cell, and inflated vegetative cells. *A* and *I* × 90; the remaining figures × 225.

provided with a conjugation canal, indicating the possibility that here conjugation with a third thread had taken place, the cell in question having behaved as a male.

The cells containing the zygospores never showed any trace of inflation, although generally rather short as compared with the ordinary vegetative

cells (*cf.* Fig. 20, *C, F, I*). As a general rule the zygospores only occupied a part of the fructifying cells (Fig. 20, *C, E*), but in some cases they almost completely filled them (Fig. 20, *F, I*). The zygospores were provided with a smooth thick membrane, generally brownish in colour, and varied very much in shape; the commonest type is shown in Fig. 20, *E* and *F*, but almost globular zygospores (Fig. 20, *C*) and such as were elongated elliptical (Fig. 20, *H*) were not infrequent. The ends were almost invariably broadly rounded (Fig. 20, *C, E, F, H*), but now and again one (Fig. 20, *G*) or, very rarely, both ends were somewhat pointed, this constituting an approach to the form of zygospore characteristic of the type. Not uncommonly small drops of oil occurred between the thick membrane and the slightly contracted contents (Fig. 20, *C, I*). The ordinary vegetative cells are not inflated, and appear in all cases to contain two chloroplasts (Fig. 20, *B–D*).

In some respects this variety resembles *S. exilis*, W. & G. S. West (Ann. Roy. Bot. Gard., Calcutta, vi, 1907, p. 186, Pl. X, figs. 11–13); this species is, however, considerably smaller, and shows the inflation of the non-conjugating cells only in the female filaments. Possibly, however, *S. exilis* would be better regarded as a variety of *S. decimina*.

The latter species is evidently of wide distribution in Africa, having been recorded from the Nyassa and Tanganyika region by G. S. West, from the Nyassa region by Schmidle (f. *fuellebornei*), from Madagascar by W. & G. S. West, and from Egypt by G. S. West.

2. *Spirogyra subreticulata* F. E. Fritsch, n. sp. (Fig. 21).

S. cellulis vegetativis diametro ad 8plo longioribus, extremitatibus non replicatis, septis saepe crassis; chromatophoris 3–4, saepe angustis, marginibus subintegris, anfractibus 2–3 vel interdum subrectis, cum pyrenoidibus conspicuis; conjugatione scalariformi, cellulis fructiferis interdum paullo in media parte inflatis, cellulis vegetativis brevioribus; zygosporis saepe tubis connexivis oppositis, lateres cellularum fructiferarum arcti tangentibus sed in directione longitudinali eas non complentibus, oblongo-ellipticis polis acutis vel subrotundatis, interdum fere subcircularibus, diam circ. $1\frac{1}{3}$–$2\frac{1}{2}$plo longioribus; membrana zygosporae crassissima, laminis ternis praedita, lamina externa tenui hyalina persistente, lamina media irregulariter reticulata luteo-fusca, lamina interna crassa brunnea.

Crass. cell. veg., 50–54 μ; crass. cell. fruct., 51–60 μ; lat. × long. zygosp., 60 × 48, 63 × 45, 70 × 42, 87 × 54, 91 × 54, 93 × 49, 94 × 48, 96 × 54, 124 × 49 μ; crass. membr. zygosp., 7–9 μ.

Samples 338, 339, and 340.

In many respects, and especially in the character of the zygospores, this species approaches *S. reticulata*, Nordst., but there are several points

of difference, viz. the threads are wider, the end-walls are not folded, there appear to be constantly three or four chloroplasts showing either a number of turns or, more rarely, running almost longitudinally, the fructifying cells are often not inflated, and, when inflation occurs, it is very slight, and the membrane of the zygospore is much thicker.

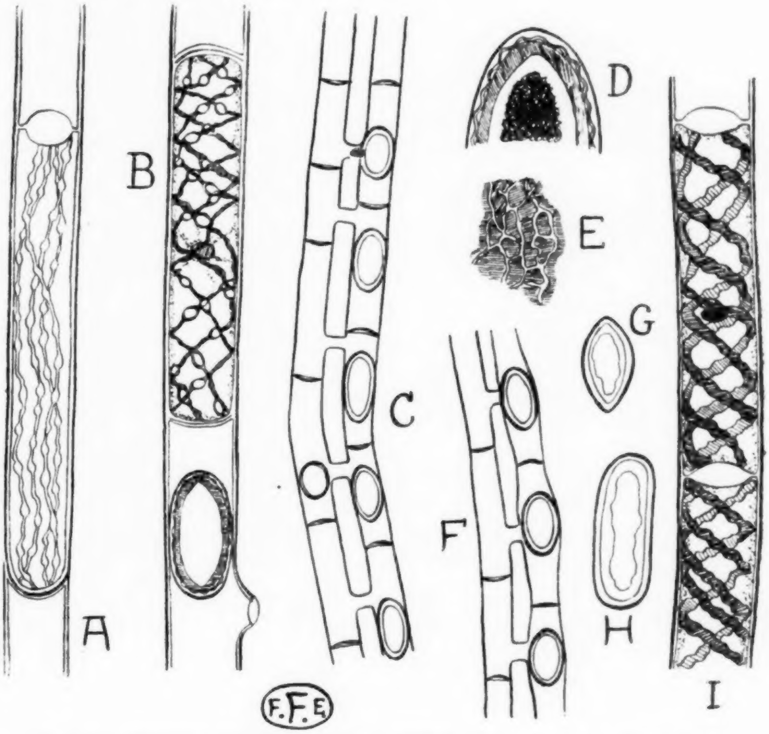


FIG. 21.—*Spirogyra subreticulata*, F. E. Fritsch, n. sp. *A* and *I*, portions of two vegetative filaments showing the varying disposition of the chloroplasts and the thick septa. *B*, *C* and *F*, threads with zygospores. *D*, part of a zygospore, on a large scale, in optical section to show the structure of the wall. *E*, surface-view of a small portion of the wall showing the reticulation of the middle layer. *G* and *H*, extreme forms of zygospores. *A*, *B* and *I* × 260; *C* and *F* × 90; *D* × 430; *E* × 860; *G* and *H* × 170.

The zygospores are rather variable as regards relation of length to breadth and also in respect of their shape. Extreme forms are shown in Fig. 21, *G* and *H*, but most commonly they are elliptical, often with somewhat pointed ends (Fig. 21, *C* and *F*). The very thick zygospore-membrane is composed of three distinct layers (Fig. 21, *D*); there may

be a fourth delicate innermost layer, but it has been impossible to arrive at a definite conclusion on this point. The outermost layer is thin, smooth and hyaline, the next is somewhat thicker, with a more or less regular reticulate sculpturing (Fig. 21, *D* and *E*) and apparently yellowish-brown colour, whilst the third is very thick, seemingly homogeneous and dark brown. The conjugating cells are generally appreciably shorter than the ordinary vegetative cells (Fig. 21, *C* and *F*), and the cells containing the zygospores are often in no way inflated (Fig. 21, *C*), although here and there a slight inflation of the middle portion is apparent (Fig. 21, *F*).

The number of chloroplasts is often three (Fig. 21, *I*), more rarely four (Fig. 21, *A* and *B*). In the sterile filaments the chloroplasts were fairly broad and the pyrenoids often not very conspicuous (Fig. 21, *I*), but in conjugating threads they usually appeared narrower, the pyrenoids forming prominent bulges (Fig. 21, *B*).

S. subreticulata may also be compared with *S. cylindrospora*, W. & G. S. West, *S. borysthenica*, Kassan et Smirnoff, and *S. paraguayensis*, Borge, all of which show prominent points of difference.

3. *Spirogyra majuscula*, Kuetzing, Spec. Alg., 1849, p. 441 : Tab. Phycol., v, 1855, Pl. XXVI, fig. 1. (Syn.: *S. orthospira*, Naeg.; Petit, *op. cit.*, p. 30, Pl. X, figs. 4, 5.)

Samples 64, 65 (common).

Lat. fil., 81–87 μ; crass. zygosp., 48–54 μ; long. zygosp., 72–91 μ. The vegetative cells were on the whole relatively short, rarely more than twice as long as broad and often not longer than broad. The dimensions, both of vegetative cells and zygospores, are larger than those given by Petit (*loc. cit.*), but in all other respects the material was quite typical.

4. *Spirogyra bellis* (Hass.), Cleve, Svenska Zygnem., p. 18, Pl. III, figs. 2–5; Petit, *op. cit.*, p. 31, Pl. X, figs. 1–3. (Syn.: *Zygnema belle*, Hassall, Brit. Freshw. Alg., 1845, p. 142, Pl. XXIV, figs. 1, 2.)

Sample 327 (common).

Lat. fil., 90–96 μ; crass. zygosp., 51–60 μ; long. zygosp., 72–84 μ. The form present resembled more closely that figured by Hassall (*loc. cit.*) than that of Petit (*loc. cit.*), the vegetative cells being very short (as long as broad or $1\frac{1}{2}$ times as long) and the zygospores having broadly rounded ends. It differed from both, however, in showing slightly larger dimensions, in the zygospores not so completely filling the fructifying cells, and in the fact that the inflation of the latter was quite commonly not very pronounced. The middle layer of the zygospore-membrane showed a faint irregular scrobiculation like that described and figured by Borge (Arkiv f. Bot., vi, No. 1, 1906, p. 11, Tab. I, fig. 3).

5. *Spirogyra fluviatilis*, Hilse in Rabenhorst, Algen, No. 1476; Borge, *op. cit.*, p. 27, fig. 33.

var. *africana*, F. E. Fritsch, nov. var. (Fig. 22).

Var. cellulis vegetativis latioribus, saepe elongatis, membranis crassis, in parte inferiore filorum etiam crassissimis, chromatophoris 3-4 anfractibus 1½-4; cellulis fructiferis valde inflatis, abbreviatis; zygosporis ovalibus, apicibus late rotundatis, cellulas sporiferas non vel fere complentibus. Membrana zygosporae crassa ferruginea, lamina media irregulariter sed dense reticulata. Cellula radicalis plus minus elongata, rhizoidiformis et

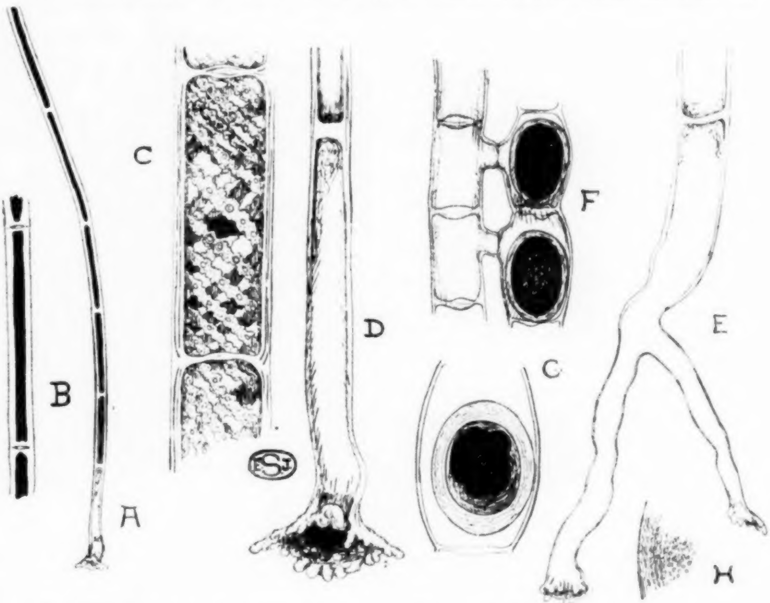


FIG. 22.—*Spirogyra fluviatilis*, Hilse, var. *africana*, F. E. Fritsch, vov. var. *A*, base of a filament showing the attaching cell and the thick-walled cells following upon it. *B*, a single one of the latter, on a larger scale. *C*, ordinary vegetative cells. *D*, rhizoid of the ordinary, and *E*, rhizoid of the branched type. *F*, small part of threads in process of conjugation. *G*, zygospore, showing structure of the membrane. *H*, small part of the latter, on a larger scale. *A* × 30; *B* × 60; *C* and *G* × 300; *D*-*F* × 135; *H* × 700 about.

vulgo contentu nullo, cellulae posteriores aut formae vulgaris aut membrana valde incrassata et contentu diminuto.

Lat. cell. veg., 54-60 μ; long. 3-10plo major; lat. cell. fruct., 90-96 μ; crass. zygosp., 63-67 μ; long. zygosp., 78-79 μ (raro longior).

Sample 331 (common, probably attached to stones in clear running water).

This variety differs from the published descriptions of *S. fluviatilis*, Hilse, in the wider vegetative cells, the frequent presence of three chloroplasts (although four are not uncommon), and in the dense reticulation of

the middle layer of the zygospore-membrane. This seems to be due to the fact that the lamellae of the middle layer are undulate, these undulations appearing as wavy lines, and, when viewed exactly from above, as dots or little papillae (*cf.* Fig. 22, *G* and *H*). It is possible that this feature of the zygospore is not really distinctive of the variety, as earlier observers may not have had mature zygospores of *S. fluviatilis* before them; immature zygospores, in the present material, showed no trace of the reticulation. Altogether our knowledge of *S. fluviatilis* is so meagre that it has been difficult to arrive at an exact conclusion as to the status of the present form.

The cell-walls, both longitudinal and transverse, are strongly thickened and often lamellated (Fig. 22, *C*). The conjugation-tubes are broad, thick-walled and very short (Fig. 22, *F*), as appears to be characteristic of *S. fluviatilis* (*cf.* Borge's figure, *loc. cit.*). Many of the threads showed well-marked attaching cells (Fig. 22, *A*), generally simple (Fig. 22, *A* and *D*), but occasionally branched (Fig. 22, *E*). The cells immediately following on these rhizoids were either of the ordinary type, or several of them were exceedingly thick-walled and provided with very attenuated contents in which no details of structure could be distinguished (Fig. 22, *A* and *B*); now and again similar cells were observed in the course of the filaments.

This variety somewhat approaches *S. fallax* (Hansg.), Wille (*S. insignis* (Hass.), Kuetz., var. *fallax*, Hansgirg, Hedwigia, 1888), in which the middle layer of the membrane of the elliptical zygospores is brown with reticulate thickenings; but this species frequently possesses folded end-walls, the chloroplasts run almost straight or exhibit fewer turns, and it does not appear to have special attaching cells in the mature condition.

6. *Spirogyra rivularis* (Hass.), Rabenhorst, Fl. Europ. Alg., iii, 1868, p. 243. (Syn.: *Zygnema rivularis*, Hassall, Brit. Freshw. Alg., 1845, p. 144, Pl. XXVII, figs. 1, 2.) (Fig. nostr. 23.)

Samples 70 (common) and 71.

Lat. cell. veg., 37–40 μ; long., 96–180 μ; crass. membr., 4·5–6 μ. I provisionally refer this form, of which only sterile material was present, to the above species, with which it seems to agree in dimensions, in the presence of two to three chloroplasts making several turns in the cells (Fig. 23, *A*), and in its habitat. The chloroplasts were very broad, with large pyrenoids, and were generally so densely arranged that it was difficult to distinguish the one from the other (Fig. 23, *A*). The membrane was usually very strongly thickened and stratified (Fig. 23, *A* and *B*), as also were the septa (which in extreme cases attained a thickness of 30 μ). The lower end of the filaments terminated in a characteristic strongly thickened attaching cell (Fig. 23, *B* and *C*), with a broadened base and scanty chlorophyll-content; in some few cases the cell next above was also provided with rather scanty contents. The upper ends of the filaments were neatly rounded off.

(NOTE.—Sterile, and therefore indeterminable, material of this genus was also encountered in the following samples: 33, 66 (several species), 86, 159, 311, 313, 314, 316, 327, 336, 339, and 344).

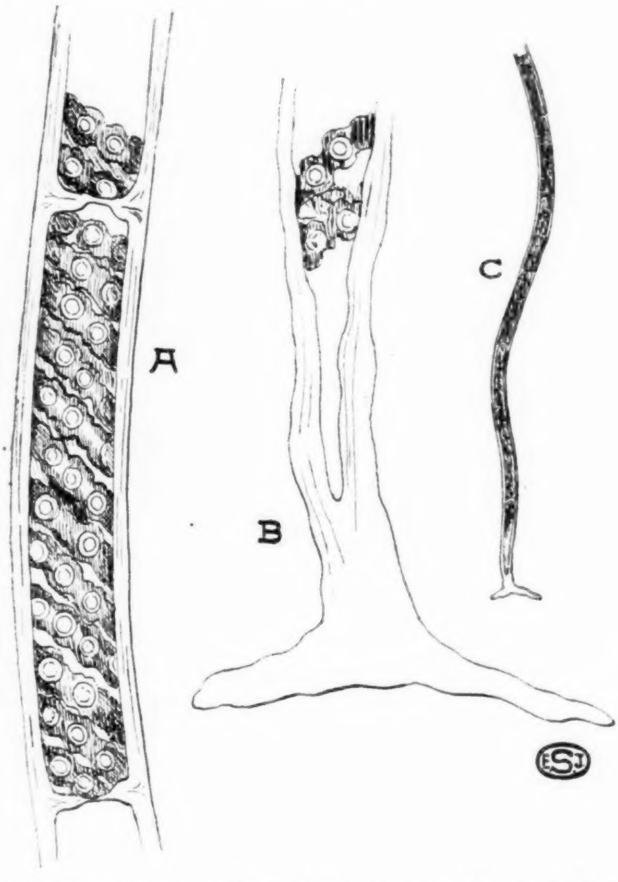


FIG. 23.—*Spirogyra rivularis* (Hass.), Rabenh. (?). *A*, small part of a filament showing the thick membrane and the arrangement of the chloroplasts. *B*, one of the attaching cells. *C*, base of a filament. *A* and *B* × 450; *C* × 50.

GENUS ZYGNEMA AGARDH.

1. *Zygnema pectinatum* (Vauch.), Agardh., Synops. alg. Scandin., 1817, p. 102; Borge, *op. cit.*, p. 33, fig. 49. (Syn.: *Zygogonium pectinatum*, Kuetz.). (Fig. nostr. 24.)

Samples 24 (rare), 36 (common, here like var. *conspicuum* (Hass.), Kirchn.).

Lat. cell. veg., 27 (sample 36) or 30 μ (sample 24) ; cells about twice as long ; dimensions of zygospores, 40 × 33 (sample 36) or 40 × 36 μ (sample 24).

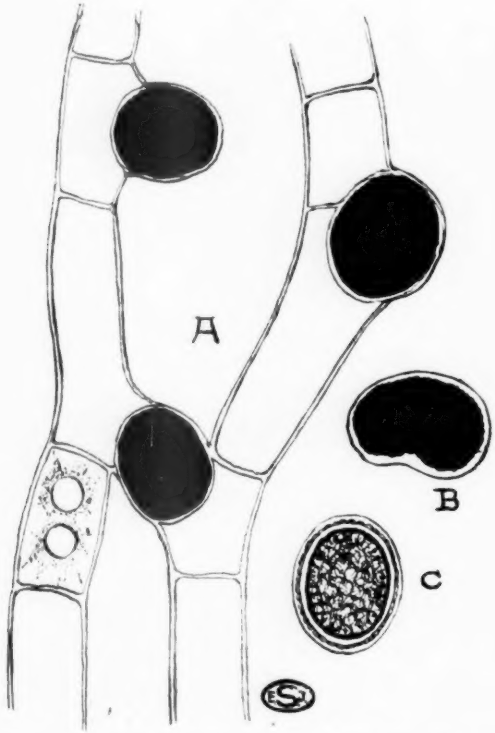


FIG. 24.—*Zygnema pectinatum* (Vauch.), Ag. *A*. Filaments showing both scalariform and lateral conjugation. *B*. Kidney-shaped zygospore, produced by lateral conjugation. *C*. Zygospore showing the characters of the membrane. × 500.

The material in sample 36 contained very plentiful conjugating filaments and zygospores, the bulk of the latter being immature ; here and there, however, typical mature spores, spherical or slightly elliptical in shape, with a brown and reticulate middle membrane were encountered (Fig. 24, *C*). The material was peculiar in the fact that many of the threads exhibited lateral conjugation, with formation of the zygospore, as in the ordinary method, in the middle of the conjugation-canal (Fig. 24, *A*), lateral and

scalariform conjugation often occurring in different parts of the same thread (Fig. 24, *A*). Lateral conjugation, among the species of the section *Zygogonium*, has hitherto only been observed in *Z. rhynchonema*, Hansg., which is a smaller species with more elongated cells. The zygospores

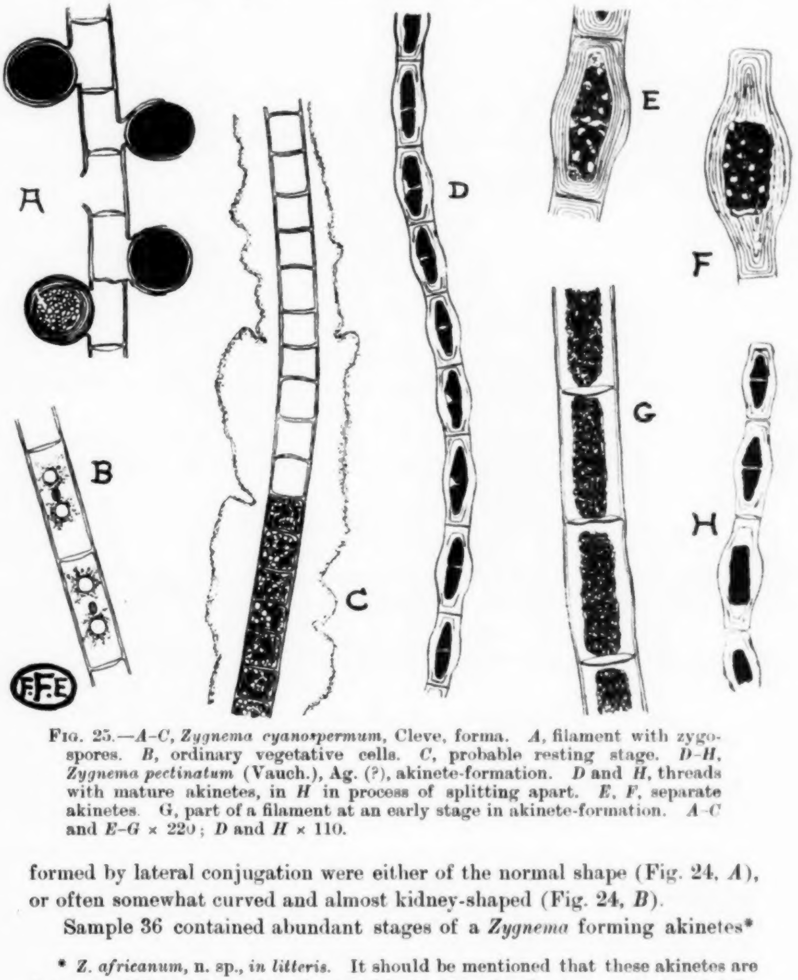


FIG. 25.—*A–C*, *Zygnema cyanospermum*, Cleve, forma. *A*, filament with zygospores. *B*, ordinary vegetative cells. *C*, probable resting stage. *D–H*, *Zygnema pectinatum* (Vauch.), Ag. (?), akinete-formation. *D* and *H*, threads with mature akinetes, in *H* in process of splitting apart. *E*, *F*, separate akinetes. G, part of a filament at an early stage in akinete-formation. *A–C* and *E–G* × 220; *D* and *H* × 110.

formed by lateral conjugation were either of the normal shape (Fig. 24, *A*), or often somewhat curved and almost kidney-shaped (Fig. 24, *B*).

Sample 36 contained abundant stages of a *Zygnema* forming akinetes*

* *Z. africanum*, n. sp., *in litteris*. It should be mentioned that these akinetes are altogether different from those described by De Bary for *Zygnema pectinatum* (*cf.* De Bary, Unters. Ueb. d. Familie der Conjugaten, 1858, pp. 9, 10, t. 1, figs. 15, 16), so that the possibility of their belonging to another species must be borne in mind.

which appear to be referable to *Z. pectinatum* (Fig. 25, *D–H*). The first step appears to consist in a marked thickening of the membrane, the thickening sometimes showing some stratification, though this is frequently obscure at this stage (Fig. 25, *G*). At the same time the cell-contents become densely crowded with food-bodies which seem in the main to be of the nature of oil-globules; this accumulation may altogether hide the two chloroplasts (Fig. 25, *G*), although in many cases their presence is indicated by a separation of the dense cell-contents into two more or less distinct halves (Fig. 25, *D* and *H*). Subsequently, as the thickening of the membrane progresses, the cells become ventricose in the middle (Fig. 25, *D* and *H*); the swelling is, however, confined to the central part of the cell, the ends having straight parallel margins for some little distance (Fig. 25, *E*, *F*). At this stage the cells may be more than twice their original width in the middle. The septa mostly become especially strongly thickened, so that the cell-contents are relegated to the median swollen part (Fig. 25, *F*), although this thickening of the septa may apparently commence at a rather later stage than that of the longitudinal walls. Ultimately these septa split across the middle (Fig. 25, *H*) and the akinetes become free. Large numbers of such splitting threads and of isolated akinetes were encountered in the sediment of Sample 36. The individual akinetes either have neatly rounded truncate ends (*cf.* the upper end in Fig. 25, *F*) or the ends bear remnants of the thickening layers (lower end of Fig. 25, *F*).

It may be added that all stages between the normal thin-walled *Zygnema pectinatum* filament and such thick-walled threads as are shown in Fig. 25, *G*, were found, and seeing that the diameter of the cell-contents of the latter is the same as that of the former, it seems fairly safe to conclude that the akinetes are those of this species.

The following is a synopsis of the dimensions of these akinetes:—

	μ	μ	μ	μ	μ	μ	μ	μ
Width of cells as in Fig. 25, *G*	36	36	37	37	39	40	42	42.
Length „ „ „ „	—	100	105	83	129	135	170	165.
Thickness of membrane of ditto	3	6	6	4·5	2·5	7·5	—	7·5.
Width of akinete in the middle	—	60	70	73	67	57	—	—
Length of akinete	—	174	200	—	—	—	—	—
Thickness of membrane in middle	—	12	12	15	15	14	—	—
„ „ „ at the apex	—	60	66	—	—	—	—	—
Width of apex	—	30	30	—	—	—	—	—

2. *Zygnema cyanospermum*, Cleve, Svenska Zygnem., Nov. Act. Reg. Soc. sc. Upsal., ser. iii, vi, 1868, No. xi, p. 28, Pl. VIII, figs. 6–8.

forma paullo major, cellulis brevioribus, 1–3plo longioribus quam latis. Lat. cell. veg., 27–30 μ; dimension. zygosp., 42 × 39, 42 × 43, 45 × 42, 48 × 48, 48 × 33 (elliptical zygospore), 50 × 48 μ. (Fig. 25, *A–C*.)

Sample 311 (not uncommon, but mainly sterile).

Z. cyanospermum, Cleve, appears hitherto only to have been recorded by Cleve from Sweden and by Larsen from Greenland. The South African specimens do not entirely agree with Cleve's diagnosis and figure, but there can be no doubt that they belong to this species. The vegetative cells and the zygospores are somewhat larger, but in no case did the length of the cells amount to more than three times the breadth; in fact in many of the threads, in which active division had evidently taken place, the length

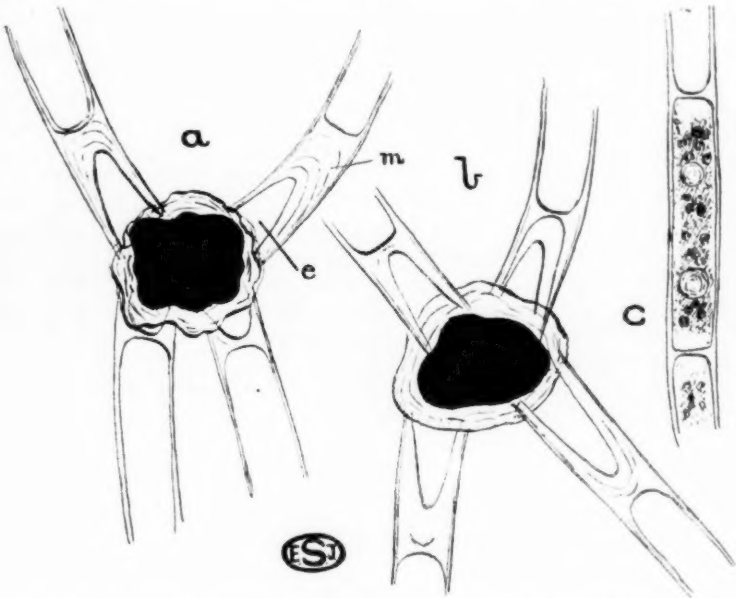


FIG. 26.—*Mougeotia uberosperma*, W. & G. S. West. *a* and *b*, cells with ripe zygospores. *c*, small part of a vegetative thread. *a* and *b* × 1000; *c* × 900.

of the cells scarcely exceeded their breadth. The zygospores were in part almost completely spherical (Fig. 25, *A*), but here and there an elliptical one was encountered. The outer layer of the zygospore-membrane is relatively thin and transparent, the second layer more or less strongly thickened (Fig. 25, *A*, lowest zygospore) and deeply pigmented, exhibiting various shades of blue, from a deep greenish-blue to a deep violet or practically black colouration.

Some of the sterile *Zygnema*-threads in the same sample, and presumably belonging to the same species, were provided with a wide and often irregular mucilage-sheath (Fig. 25, *C*). A few of these threads, with an especially

wide sheath, were composed of cells with dense granular contents including large shining drops of some oily material (Fig. 25, *C*). These are probably resting-stages of this species.

(NOTE.—Sterile, indeterminable material of *Zygnema* was also observed in samples 64, 65, 85, 86, 159, 312, 314, 316, and 327.)

(4) MESOCARPACEAE.

GENUS MOUGEOTIA AGARDH.

1. *Mougeotia uberosperma*, W. & G. S. West, Welwitsch's Afr. Freshw. Alg., Journ. of Bot., 1897, p. 37. (Fig. 26.)

Sample 36 (rare).

Lat. cell. veg., 7–9 μ; long. cell. veg., 30–34 μ; diam. zygosp. sine proc., 24–25 μ; crass. membr. zygosp., 3·5–4·5 μ; long. proc., usque 18 μ.

This small species has hitherto only been recorded from Huilla and its rediscovery in Kentani is interesting. The zygospores are very characteristic, being irregularly angular-globose (Fig. 26, *a* and *b*), with a thick, colourless, plainly stratified wall and bearing four processes of very unequal length. The processes are homogeneous and apparently mucilaginous in nature and are more or less pointed when long, though blunt when short (Fig. 26, *a* and *b*); they extend for a variable distance into the cavities of the conjugating cells. The unoccupied part of the latter would also appear in some cases to become filled up with some distinctly stratified material (Fig. 26, *a*, *m*).

(NOTE.—Sterile material of *Mougeotia* was also observed in samples 64, 66, 311, 312, 315, and 327.)

II. HETEROKONTAE.

(4) TRIBONEMACEAE.

GENUS OPHIOCYTIUM NAEGELI.

1. *Ophiocytium majus*, Naegeli, Gatt. einzell. Alg., 1848, p. 89, Pl. IV, A, fig. 2; Heering, Suesswasseralg. Schleswig-Holsteins, etc., i, 1906, p. 120, fig. 25.

Sample 22.

Previously recorded from the Cape (Fritsch).

2. *Ophiocytium parvulum* (Perty), A. Braun, Alg. unicell., etc., 1855 p. 55; Heering, *op. cit.*, p. 124, fig. 31.

Samples 20, 21, 22, 338, 339.
Previously recorded from the Cape (Fritsch).

3. *Ophiocytium cochleare* (Eichw.), A. Braun, *op. cit.*, p. 54; Heering, *op. cit.*, p. 121, fig. 26.
Samples 22, 338, 339.
Previously recorded from the Cape (Nordstedt).

4. *Ophiocytium gracilipes* (A. Braun), Rabenhorst, Fl. Europ. Alg., iii, 1868, p. 68; Heering, *op. cit.*, p. 118, fig. 24, *a, d.* (Syn.: *Sciadium gracilipes*, A. Braun.)
Sample 29 (rather common).

GENUS TRIBONEMA DERBÈS ET SOLIER.

1. *Tribonema bombycinum*, Derbès et Solier, Mém. sur q. points d. l. physiol. d. algues, Suppl. aux Comptes rendues, i, 1856, p. 18; Heering, *op. cit.*, p. 131, fig. 36. (Syn.: *Conferva bombycina*, Ag.).
Forma *minor*, Wille.
Samples 19, 20, 21, 22, 29, 86, 334, 342, 346.
Previously recorded from the Cape (Fritsch).

III. CYANOPHYCEAE (MYXOPHYCEAE).

(*a*) CHROOCOCCALES.

(1) CHROOCOCCACEAE.

GENUS CHROOCOCCUS NAEGELI.

1. *Chroococcus minutus* (Kuetz.), Naegeli, Gatt. einzell. Alg., 1849, p. 46; Forti, Sylloge Myxophyc., 1907, p. 14.
Sample 326 (rather common).
Previously recorded from South Africa (Wille), Great Namaqualand (G. S. West), and the Cape (Fritsch).

2. *Chroococcus minor* (Kuetz.), Naegeli, *op. cit.*, p. 47, Pl. I, A, fig. 4; Forti, *op. cit.*, p. 23.
Sample 71.
Previously recorded from the Karoo, Little and Great Namaqualand (G. S. West).

3. *Chroococcus turgidus* (Kuetz.), Naegeli, *op. cit.*, p. 46; Forti, *op. cit.*, p. 11. (Syn.: *Protococcus turgidus*, Kuetzing, Tab. Phycol., i, Tab. VI, fig. 1.)
Samples 158, 159, 311, 314, 315 (rather common), 324 (here on *Phormidium fragile*), 326 (very rare).
Diam. cell., 10–30 μ.

Previously recorded from the Cape region, Little Namaqualand, and Holle River (G. S. West).

Genus GLOEOTHECE Naegeli.

1. *Gloeothece linearis*, Naegeli, *op. cit.*, p. 58, Tab. I, G, fig. 2; Forti, *op. cit.*, p. 62.

Samples 159 (rare) and 324 (very common).

Lat. cell., 2–2·5 μ; long. cell., 10–15 μ. The sheaths of the individual cells were very difficult to decipher, even after staining. The cells were very variable in form, short straight rods with rounded or pointed ends being most common, but lunate and faintly sigmoid shapes were not infrequent. A few cells were also observed in which one side was flat and the other convex.

2. *Gloeothece confluens*, Naegeli, *op. cit.*, p. 58, Tab. I, G, fig. 1; Forti, *op. cit.*, p. 60.

Sample 159.

Genus APHANOTHECE Naegeli.

1. *Aphanothece microscopica*, Naegeli, *op. cit.*, p. 59, Tab. I, H, fig. 1; Forti, *op. cit.*, p. 83.

Sample 85.

Genus MICROCYSTIS Kuetzing.

1. *Microcystis parasitica*, Kuetzing, Phycol. generalis, 1843, p. 170; Phycol. german., 1845, p. 148; Tab. Phycol., i, 1846, Tab. IX; Forti, *op. cit.*, p. 91; Fritsch, Freshw. Alg., Nat. Antarct. Exped., vi, 1912, p. 24, Pl. I, figs. 67–70. (Syn.: *Microcystis firma* (Bréb. et Lenorm.), Migula.)

Sample 324 (common, on *Phormidium fragile*.)

2. *Microcystis chroococcoidea*, W. & G. S. West, Freshw. Alg., Brit. Antarct. Exped. 1907–9, vii, 1911, p. 296, Pl. XXVI, figs. 107–114.

Sample 324 (rather rare, on *Phormidium fragile*).

Colonies of small cells (diam., 4 μ). This species has hitherto only been recorded from the Antarctic (by W. & G. S. West and F. E. Fritsch).

Genus GOMPHOSPHAERIA Kuetzing.

1. *Gomphosphaeria aponina*, Kuetzing, Alg. aq. dulc. german., Decas 16, 1836, No. 151; Tab. Phycol., i, 1846, p. 22, Tab. XXXI, fig. 3; Forti, *op. cit.*, p. 97.

Samples 159 (common), 312, 325, 326.

Previously recorded from Little Namaqualand (G. S. West).

Genus COELOSPHAERIUM Naegeli.

1. ***Coelosphaerium kuetzingianum***, Naegeli, *op. cit.*, p. 54, Tab. I, c; Forti, *op. cit.*, p. 100.

Sample 158 (rare).

Genus MERISMOPEDIA Meyen.

1. ***Merismopedia glauca*** (Ehrenb.), Naegeli, *op. cit.*, p. 55, Pl. I, d, fig. 1; Forti, *op. cit.*, p. 105.

Samples 159 (common), 311, 312, 314, 315 (in the last rather common).

Previously recorded from South Africa (Wille), Little Namaqualand (G. S. West), and Orange Free State (Fritsch).

2. ***Merismopedia punctata***, Meyen, in Wiegman, Archiv, 1839, p. 67; Kuetzing, Tab. Phycol., v, 1855, Tab. XXXVIII, fig. 3; Forti, *op. cit.*, p. 106.

Sample 159 (rather common).

Previously recorded from Little Namaqualand (G. S. West).

(2) GLAUCOCYSTACEAE.

Genus GLAUCOCYSTIS Itzigsohn.

1. ***Glaucocystis nostochinearum***, Itzigsohn, in Rabenhorst, Alg. exsicc., No. 1935; Fl. Europ. Alg., iii, 1868, p. 417, fig.; Forti, *op. cit.*, p. 693.

Sample 36 (very rare).

(*b*) CHAMAESIPHONALES.

(1) CHAMAESIPHONACEAE.

Genus CHAMAESIPHON Braun et Grunow.

1. ***Chamaesiphon incrustans***, Grun.; Rabenhorst, *op. cit.*, ii, 1865, p. 149; Forti, *op. cit.*, p. 136.

Samples 325 (on *Cladophora*, sp.), and 331 (on *Spirogyra fluviatilis* var. *africana* and *Oedogonium*, sp.).

Previously recorded from Orange Free State (Fritsch).

(*c*) HORMOGONEALES.

(1) OSCILLATORIACEAE.

Genus OSCILLATORIA Vaucher.

1. ***Oscillatoria princeps***, Vaucher, Hist. d. Conferv. d'eau douce, 1803, p. 190, Tab. XV, fig. 2; Gomont, Monogr. d. Oscillariées, Ann. sci. nat., sér. 7, xvi, 1893, p. 206, Pl. VI, fig. 9.

Sample 161 (rather common).

Diam. trich., 21–30 μ.

Previously recorded from the Karoo by G. S. West.

2. *Oscillatoria sancta*, Kuetzing, Tab. Phycol., i, 1845, p. 30, Tab. XLII, fig. 7; Gomont, *op. cit.*, p. 209, Pl. VI, fig. 12.

Sample 326 (common).

Diam. trich., 16 μ.

3. *Oscillatoria limosa*, Agardh, Disp. Alg. Suec., 1812, p. 35; Gomont, *op. cit.*, p. 210, Pl. VI, fig. 13.

Sample 158 (rather rare).

Previously recorded from Holle River, Calvinia Division (G. S. West), and Orange Free State (Fritsch).

4. *Oscillatoria tenuis*, Agardh, Alg. Decades, ii, 1813, p. 25; Gomont, *op. cit.*, p. 220, Pl. VII, figs. 2, 3.

Samples 23, 24, 28 (here very rare), 336.

Previously recorded from Holle River, Calvinia Division (G. S. West), Little Namaqualand (G. S. West), the Cape (Fritsch), and Madagascar (Fritsch).

5. *Oscillatoria geminata*, Meneghini, Consp. alg. eugan., 1837, p. 9; Gomont, *op. cit.*, p. 222, Pl. VII, fig. 6.

Sample 346 (common).

6. *Oscillatoria splendida*, Greville, Fl. edinensis, 1824, p. 305; Gomont, *op. cit.*, p. 224, Pl. VII, figs. 7, 8.

Sample 324 (common).

Forming dense tufts on the surface of *Phormidium fragile*; diam. trich., 2·5–3 μ.

7. *Oscillatoria animalis*, Agardh, in Flora, x, 1827, p. 632; Gomont, *op. cit.*, p. 227, Pl. VII, fig. 13.

Samples 161, 312.

Previously recorded from Little Namaqualand (G. S. West), and South Africa (Wille).

8. *Oscillatoria brevis*, Kuetzing, Phyc. generalis, 1843, p. 186; Gomont, *op. cit.*, p. 229, Pl. VII, figs. 14, 15.

Sample 86.

9. *Oscillatoria formosa*, Bory, Dict. Class. d'hist. Nat., xii, 1827, p. 474; Gomont, *op. cit.*, p. 230, Pl. VII, fig. 16.

Samples 324, 326.

Diam. trich., 6 μ.

Previously recorded from Little Namaqualand (G. S. West) and the Cape (Fritsch).

10. *Oscillatoria subtilissima*, Kuetzing, Tab. Phycol., i, 1845, p. 27, Tab. XXXVIII, fig. 8; Forti, *op. cit.*, p. 171.

Sample 335 (rather common).

This form occurred on the surface of the investment of *Nostoc* sp. The trichomes (diam., 1·5 μ) in part formed almost parallel bundles, in part were rolled up in a circinate manner. They showed a faint constriction at the dissepiments, which were fairly conspicuous. It has been suggested that this species may be a form of *Lyngbya rivulariorum*, Gom. (*cf.* Ann. S. Afr. Mus., ix, 1918, p. 574), and the mode of occurrence of the present material is not in disagreement with this.

Genus SPIRULINA Turpin.

1. *Spirulina major*, Kuetzing, Phycol. generalis, 1843, p. 183; Gomont, *op. cit.*, p. 251, Pl. VII, fig. 29.

Sample 326 (rather rare).

Previously recorded from Little Namaqualand (G. S. West), the Cape and Orange Free State (Fritsch).

Genus PHORMIDIUM Kuetzing.

1. *Phormidium fragile*, Gomont, *op. cit.*, p. 163, Pl. IV, figs. 13–15.

Sample 324 (bearing numerous epiphytes: *Oscillatoria splendida*, *Lyngbya aestuarii*, *Chroococcus turgidus*, *Microcystis* spp., *Microcoleus chthonoplastes*, *Anabaena torulosa*).

Previously recorded from Holle River (G. S. West).

2. *Phormidium valderianum*, Gomont, *op. cit.*, p. 167, Pl. IV, fig. 20.

Sample 159 (rather common).

Previously recorded from Cape Town (Fritsch).

3. *Phormidium laminosum*, Gomont, *op. cit.*, p. 167, Pl. IV, figs. 21, 22.

Sample 81.

Previously recorded from Little Namaqualand and Holle River (G. S. West).

4. *Phormidium tenue*, Gomont, *op. cit.*, p. 169, Pl. IV, figs. 23–25.

Samples 71, 85.

Previously recorded from Holle River and Little Namaqualand (G. S. West).

5. *Phormidium inundatum*, Kuetzing, Spec. Alg., 1849, p. 251; Gomont, *op. cit.*, p. 172, Pl. IV, figs. 31, 32.

Sample 68.

Diam. fil., 4–6 μ.

6. *Phormidium subfuscum*, Kuetzing, Phycol. generalis, 1843, p. 195; Gomont, *op. cit.*, p. 182, Pl. V, figs. 17–20.

Sample 326.

Diam. fil., 10–11 μ.

Previously recorded from Table Mountain (Fritsch).

7. *Phormidium autumnale*, Gomont, *op. cit.*, p. 187, Pl. V, figs. 23, 24. (Syn.: *P. uncinatum*, Gom.)

Samples 69, 79, 82, and 84.

Previously recorded from the Cape Province (Fritsch).

Genus LYNGBYA C. Agardh.

1. *Lyngbya aestuarii*, Liebman, Bemerkn. og till. dansk. Algefl., Kroeyer's Tidsskrift, 1841, p. 492; Gomont, *op. cit.*, p. 127, Pl. III, figs. 1, 2.

Sample 324 (rather common, on *Phormidium fragile*).

Diam. fil., 18–20 μ.

2. *Lyngbya major*, Meneghini, Consp. alg. eugan., 1837, p. 12; Gomont, *op. cit.*, p. 144, Pl. III, fig. 15.

Sample 24 (rare).

Previously recorded from South Africa (Wille), Little Namaqualand (G. S. West), and the Cape (Fritsch).

3. *Lyngbya aerugineo-coerulea*, Gomont, *op. cit.*, p. 146, Pl. IV, figs. 1–3.

Sample 329 (rather common).

Diam. trich., 4–5 μ. The trichomes did not exhibit any specially differentiated apical cell, although there was sometimes a slight thickening of the outer wall of the end-cell. The septa were often very indistinct and not granulated and the cell-contents in many of the trichomes very homogeneous. Such forms come very close to *L. cladophorae*, Tilden (Minnesota Algae, i, 1910, p. 116, Pl. V, fig. 34), which is probably but a form of *L. aerugineo-coerulea*. The species has been previously recorded from Table Mountain (Fritsch).

4. *Lyngbya kuetzingii*, Schmidle, Algol. Not., iv, Allgem. bot. Zeitschr., 1896, p. 58; Forti, *op. cit.*, p. 280.

Var. *distincta* (Nordst.), Lemmermann, Engler's Bot. Jahrb., xxxiv, 1905, p. 620. (Syn.: *L. subtilis*, W. West; *L. distincta*, Schmidle.)

Sample 24 (rather common, on *Vaucheria* sp.).

Lat. fil., 1·8 μ.

Previously recorded from the Cape (Fritsch).

GENUS MICROCOLEUS DESMAZIÈRES.

1. *Microcoleus chthonoplastes*, Thuret, Essai d. classif. d. Nostochinées, Ann. sci. nat., sér. 6, Bot., i, 1875, p. 378; Gomont, *op. cit.*, xv, 1893, p. 353, Pl. XIV, figs. 5–8.
Sample 324 (rare, on *Phormidium fragile*).
Diam. trich., 6 μ.

GENUS SCHIZOTHRIX KUETZING.

1. *Schizothrix calcicola*, Gomont, *op. cit.*, p. 307, Pl. VIII, figs. 1–3.
Sample 345 (common).

(2) NOSTOCACEAE.

GENUS NOSTOC VAUCHER.

1. *Nostoc caeruleum*, Lyngb.; Bornet et Flahault, Rev. d. Nostoc. hétérocyst., Ann. sci. nat., Bot., sér. 7, vii, 1888, p. 213; Forti, *op. cit.*, p. 416.
Sample 82.

2. *Nostoc muscorum*, Agardh, Disp. Alg. Suec., 1812, p. 44; Bornet et Flahault, *op. cit.*, p. 200; Forti, *op. cit.*, p. 400.
Sample 85 (with spores).
In sample 87 there occurred another *Nostoc* which may possibly belong to this species; the material, however, showed no spores and was poorly preserved.

3. *Nostoc* sp. (*verrucosum* (L.), Vauch.?).
Sample 335.
In the absence of spores it is not possible to make sure of this determination. The trichomes were very regularly cylindrical, the cells depressed-spherical, and the heterocysts spherical. Diam. cell., 4 μ; diam. heterocyst., 7–8 μ.

GENUS ANABAENA BORY.

1. ? *Anabaena inaequalis* (Kuetz.), Bornet et Flahault, *op. cit.*, p. 231. (Fig. 27.)
Sample 29 (for the most part epiphytic on *Oedogonium* sp.).
This is the same form as has been recorded from Camps Bay in the Cape Peninsula and from Riet River, Orange Free State (*cf.* Fritsch, *loc. cit.*, p. 578). It has a marked epiphytic tendency, occurring in the present sample mainly on a species of *Oedogonium*. The trichomes are often rather straight and are provided with a delicate close-fitting sheath (Fig. 27, *B*);

not uncommonly several of them occur together in a common sheath (Fig. 27, *A*). The vegetative cells are 5–6 μ in diameter (rather wider dimensions were observed in the other South African material); the heterocysts are slightly wider and spherical or somewhat elliptical in shape (Fig. 27).

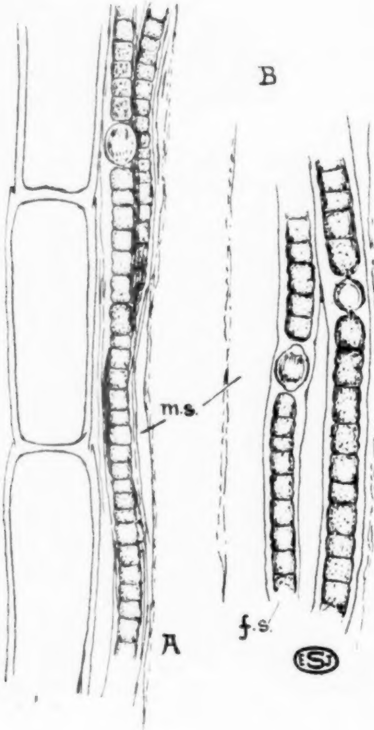


Fig. 27.—*Anabaena inaequalis* (Kuetz.), Bornet et Flahault (?). *A*, showing several trichomes in a common sheath. *B*, separate trichomes. *m.s.*, mucilage-sheath; *f.s.*, sheath of individual trichome. × 1000.

This form has been referred to the above species because of its general habit and other points of agreement, but in the absence of spores the reference is uncertain. The frequent elliptical shape of the heterocysts is a point of divergence, but it may be noted that G. S. West (Brit. Freshw. Alg., 1904, p. 328, fig. 150, *B*, *C*) figures heterocysts, which are elliptical, for this species.

2. ***Anabaena torulosa*** (Carm.), Lagerheim, Bidr. Sv. Algfl., Oefvers. K. Vet.-Akad. Foerhandl., 1883, No. 2, p. 47; Bornet et Flahault, *op. cit.*, p. 236.

Sample 324 (rare, on surface of *Phormidium fragile*).

Diam. cell., 4·5 μ; diam. heterocyst., 6 μ; lat. spor., 6–7·5 μ; long. spor., 15–18 μ. Spores contiguous to heterocysts, often somewhat hour-glass-shaped. This species does not appear to be very sharply distinguished from *A. catenula* (Kuetz.), Bornet et Flahault.

(Note.—An indeterminable species of *Anabaena* was also observed in sample 327.)

(3) SCYTONEMATACEAE.

Genus SCYTONEMA Agardh.

1. *Scytonema* sp. (*stuposum* (Kuetz.), Bornet?).

Sample 327.

Diam. fil., 21–27 μ; diam. trich., 18–20 μ. Heterocysts flattened, sometimes hour-glass-shaped; cell-contents often violet. The material was inadequate for satisfactory determination.

(4) STIGONEMATACEAE.

Genus STIGONEMA Agardh.

1. *Stigonema turfaceum* (Berkeley), Cooke, Brit. Freshw. Alg., 1882–84, p. 272, Pl. CXI, fig. 2; Bornet et Flahault, *op. cit.*, sér. 7, v, 1887, p. 74.

Sample 36 (rare).

Diam. fil., 33 μ.

(5) RIVULARIACEAE.

Genus CALOTHRIX Agardh.

1. *Calothrix gracilis*, F. E. Fritsch, Freshw. Alg., in Rep. Nat. Antarct. Exped., vi, 1912, p. 37, Pl. III, figs. 164–172.

Forma *flexuosa*, n. f. (Fig. 28).

Filis plerumque valde flexuosis, gregariis, cellula apicali saepe subacuta. Diam. fil. ad bas., 6–7 μ; diam. trich. ad bas., 5–6 μ; diam. fil. in media parte, 4–5 μ; diam. trich. in media parte, 3–3·5 μ; diam. heterocyst., 5–6 μ; diam. spor. immatur., 6 μ, long., 9 μ.

Sample 327 (common as an epiphyte on fragments of water-plants and on filaments with zygospores of *Spirogyra bellis*).

This differs somewhat from the Antarctic form originally described, especially in the highly flexuous character of the filaments, which are often very densely aggregated on the substratum, and in the fact that the apical cells of the trichomes are usually more rounded than in the type, being bluntly pointed rather than conical. The material, however, agrees in all

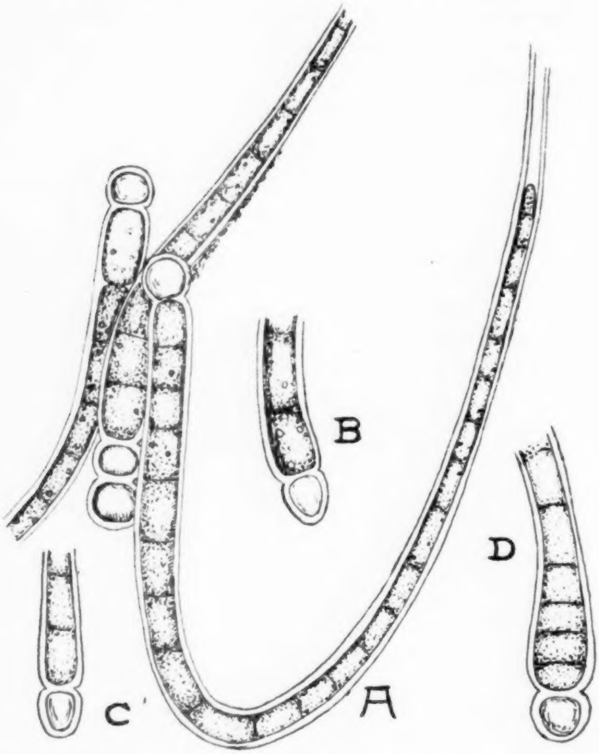


FIG. 28.—*Calothrix gracilis*, F. E. Fritsch, forma *flexuosa*, n. f. *A*, group of filaments, the left-hand one with a young spore. *B*, base of a filament with a conical heterocyst and a developing spore. *C* and *D*, bases of other filaments. All figures × 1000.

other essential respects with that from the Antarctic, and it is probable that it belongs to the same species. The heterocysts exhibit the same diversity of form as was commented upon in the description of the species. Ripe spores were not observed, but the young stages seem similar to those of the type (Fig. 28, *A* and *B*).

There are not many epiphytic species of *Calothrix* possessing the small dimensions of *C. gracilis*, and these are all distinguished by the termination of the trichome in a hair. *C. epiphytica*, W. & G. S. West, also differs in the thicker sheath, whilst *C. scytonemicola*, Tilden, is stated to have indistinct sheaths and usually two basal heterocysts.

(NOTE.—Indeterminable material of this genus was also present in samples 81, 85 (*C. adscendens* (Naeg.), Born. et Flah.?), 329, 335, 345.)

IV. FLORIDEAE.

(1) HELMINTHOCLADIACEAE.

GENUS CHANTRANSIA FRIES.

1. *Chantransia chalybea*, Fries; Kuetzing, Spec. Alg., 1849, p. 429; Tab. Phycol., V, t. 41.

Sample 33 (not uncommon).

It has been established that this is actually a stage in the development of *Batrachospermum*, but in the somewhat unusual habitat development to the adult form is not likely.

V. FLAGELLATA.

EUGLENINAE.

(1) EUGLENACEAE.

GENUS EUGLENA EHRENB.

1. *Euglena spirogyra*, Ehrenb.; Lemmermann, in Pascher, Suesswasserfl. Deutschlands, etc., Heft 2, 1913, p. 131, fig. 208. (Fig. 29, *A*.)

Sample 19 (common), 29 (very rare).

The majority of the individuals possessed the straight body and straight posterior spine shown in Fig. 29, *A*, but occasionally the body had a slight spiral twist or the spine was bent to one side. The spirally arranged rows of granules on the periplast were very obvious, but appeared all to be of the same size, whereas the type is described as usually having two rows of smaller granules between each pair of larger ones. These granules are so numerous that they give the outline of the *Euglena*, as seen in optical section, a faintly crenate appearance. The angle made by the rows of granules with the main axis of the body varies somewhat, the rows

sometimes running almost longitudinally. The two paramylon bodies were always very conspicuous, the nucleus either lying between (Fig. 29, *A*) or behind them. The dimensions were: long. sine spin., 84–87 μ; lat., 10–14 μ.

2. *Euglena viridis*, Ehrenb.; Lemmermann, *loc. cit.*, p. 127, fig. 189.
Sample 161 (rare).
Long., 54 μ; lat., 12–14 μ.

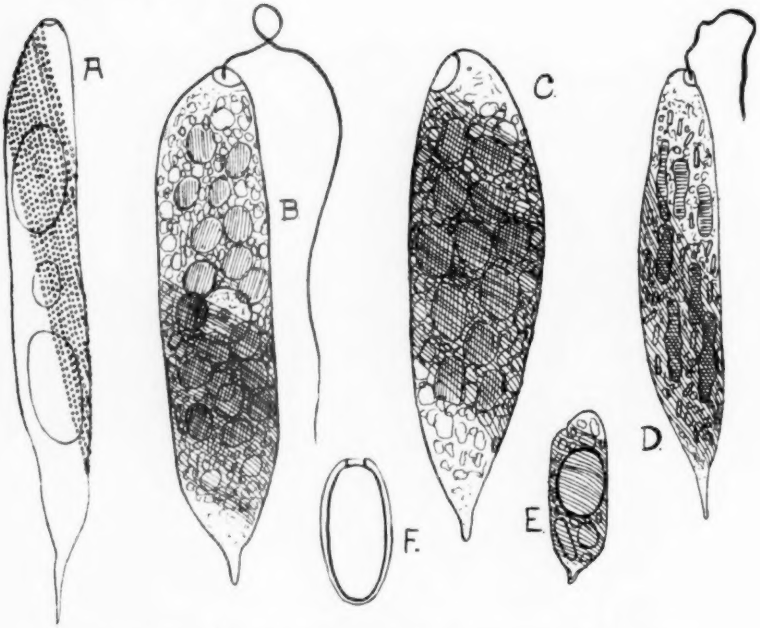


FIG. 29.—*A*, *Euglena spirogyra*, Ehrenb. (of the cell-contents only the nucleus and the two paramylon-bodies are shown). *B* and *C*, *E. proxima*, Dangeard (?). *D*, *E. terricola* (Dang.), Lemmerm. (?). *E*, *Phacus oscillans*, Klebs. *F*, *Trachelomonas cylindrica*, Ehrenb. In *A–D* the striation of the periplast is in all cases shown only on part of the individual. All figures × 930.

3. *Euglena proxima*, Dangeard; Lemmermann, *loc. cit.*, p. 129, fig. 193. (Fig. 29, *B* and *C*.)
Sample 161 (common).

Although the material was fairly well preserved, the cell-contents were not sufficiently clear to make certain of this determination. The specimens, however, agree rather well with the diagnosis of the species given by Lemmermann. In many cases the long flagellum was recognisable. As

regards the cell-contents, whilst the presence of discoid chloroplasts is undoubted, they were not nearly as numerous as shown by Lemmermann. Definite ring-shaped paramylon-grains were also not recognised, but a large central nucleus was visible in several specimens, one of which is shown in Fig. 29, *B*. The shape exhibited by this individual was not uncommon, but the type represented in Fig. 29, *C*, which comes nearer to Lemmermann's figure and description, was also frequently seen. The delicate spiral striation of the periplast was very prominent. The dimensions were: long., 70–81 μ; lat., 18–20 μ.

4. ? ***Euglena terricola*** (Dang.), Lemmermann, *loc. cit.*, p. 125, fig. 187. (Fig. 29, *D*.)

Sample 161 (rather rare).

Side by side with *E. viridis* and the form called *E. proxima* above there occurred another very slender species, the individuals of which were often roughly cylindrical, though sometimes of the form shown in Fig. 29, *D*. In a very few cases a small number of band-shaped chloroplasts were recognisable within the cell-contents and one of these specimens possessed a short flagellum (Fig. 29, *D*). These features and the presence of small rod-shaped paramylon-bodies are the grounds for referring these specimens to the above species, in the hope that a local observer may be able to verify the determination on living material. The spiral marking of the periplast was very faint and delicate. The dimensions were: long., 54–60 μ; lat., 10–12 μ.

(NOTE.—Indeterminable material of this genus was also present in samples 67, 99, 340, and 346.)

GENUS PHACUS DUJARDIN.

1. ***Phacus pleuronectes*** (O. F. M.), Duj.; Lemmermann, *loc. cit.*, p. 138, fig. 236.

Sample 338 (rare).

Previously recorded from Cape Town (Fritsch).

2. ***Phacus oscillans***, Klebs; Lemmermann, *loc. cit.*, p. 141, fig. 225. (Fig. 29, *E*.)

Sample 338 (rare).

Long., 26 μ; lat., 10 μ.

Relatively few specimens of this form have been seen but they all exhibited the above dimensions. They also agree with Klebs' form in shape, the possession of a single large paramylon-grain, and the spiral striation of the periplast.

GENUS TRACHELOMONAS EHRENBERG.

1. *Trachelomonas volvocina*, Ehrenb.; Lemmermann, *loc. cit.*, p. 145, fig. 246.

Sample 22, 30 (common), 69 (very rare), 71 (very rare), 312, and 314.

Previously recorded from Cape Town (Fritsch).

2. *Trachelomonas oblonga*, Lemmermann, *loc. cit.*, p. 147, fig. 278.

Samples 19 and 29.

Long., 13 μ; lat., 11 μ.

Previously recorded from Cape Town (Fritsch).

3. *Trachelomonas cylindrica*, Ehrenb. (*T. euchlora* (Ehrenb.), Lemm., var. *cylindrica* (Ehrenb.), Lemmermann, *loc. cit.*, p. 147). (Fig. 29, *F*.)

Samples 19, 20, 21, 22, 30 (rather rare).

Long., 18–20 μ; lat., 10–11 μ; lat. oris, 3–4 μ.

The elongated tests were somewhat truncated at the front end and slightly attenuated towards the back end, with an often wide aperture which projected at the most only to a very slight extent (Fig. 29, *F*). The membrane was commonly rather thinner at the back end than elsewhere. The sides were not exactly parallel, and hence the reference to *T. cylindrica* must be regarded as somewhat uncertain, although the form seems to come nearest to this species. *T. cylindrica* does not seem to belong to *T. euchlora*, in which the collar is apparently always oblique.

4. *Trachelomonas hispida* (Perty), Stein; Lemmermann, *loc. cit.*, p. 149, fig. 272.

Samples 19, 20, 29 (common), 30 (common), 158.

Var. *punctata*, Lemmermann, *loc. cit.*, p. 150.

Samples 19, 20, and 21 (in all three cases rather common), 22.

Both the type and var. *hispida* have been previously recorded from the Cape (Fritsch) and the type from Madagascar (Fritsch).

VI. PERIDINEAE (DINOFLAGELLATA).

Species of *Peridinium* were encountered in samples 311 and 312, but were not present in sufficient numbers for adequate determination.

A NOTE ON THE WHALES FREQUENTING SOUTH AFRICAN WATERS.

By Dr. L. Péringuey.

(With Plate I.)

The number of species of Whales frequenting our coasts is still under discussion. It seems desirable to mention here those that have come under any observations, leaving for another more elaborate note an account of notes and observations on their peculiarities and etiology.

Apart from the Cachalot or Sperm Whale, found in all the warm seas, we have two True Whales, five Fin-Whales and one Hump-back Whale.

The True Whales are :

(1) *Balaena australis*, the True Whale, which has not been met apparently south of lat. 60° S. It is not common by any means on our coasts. In former years the females of those met either in False Bay or Table Bay were either heavy in calf or accompanied by their offspring.

(2) *Neobalaena marginata*, the Pigmy Whale. It is a small species from the Australian, New Zealand and South American seas. Some three years ago a male, 11 ft. in length, was captured in False Bay. The skeleton is in our Museum. It is the first time, as far as I know, that this rare whale has been recorded in our latitude.

The Fin-Whales or Rorquals are : (1) *Balaenoptera musculus*, also known as *B. sibbaldi*, the Blue Whale. It is the largest animal alive, and probably the largest animal that ever appeared on earth. I have now trustworthy evidence of a measurement of 102 ft. 4 in., and of another example that was by several feet longer than the hauling slip of 100 ft. ; part of the tail was still in the water. We had last year presented to the Museum a pair of the lower jaws measuring 22 ft. 9 in. in the curve. The jaws of a 75 ft. skeleton of the same species measure 18 ft. 6 in., and the probability is that the former belonged to an animal near or possibly more than 100 ft. in length. It has a wide distribution, from the Northern to Southern Hemisphere.

(2) *Balaenoptera physalus* L., the Rorqual of the French, Rohrval of the Norwegian, Finner or Common Fin Whale of the English. This species does not reach the size of the Blue Whale. It measures from 40 to 70 ft., rarely exceeding this figure. It is abundant throughout the more northern seas of Europe and appears to be so in the southern seas or Antarctic.

(3) *Balaenoptera borealis* Less., the Fin-Whale or Herring-Whale, also Rudolphi's Whale, Sijhval or Seihwal of the Norwegian, Northern Rorqual of the French.

Its greatest length appears to be 45 to 50 ft. The animal was considered as rare in the Northern Hemisphere. It occurs also round the South Shetland and South Orkneys, and Amundsen met with a great number near the ice barrier. It is, therefore, the Whale that reaches furthest south.

(4) *Balaenoptera brydei* Ols. This species is very closely allied in general appearance to *B. borealis*, but the differences pointed out by Mr. Olsen have to a certain extent been verified by me or tally with information obtained from other quarters. It may be said to be more essentially ichthyophagous along our coast than even *B. borealis*; this seems to be borne out by the consistency of the fringe of the baleen, which is much coarser than that of *B. borealis*, itself an ichthyophagous species like *B. physalus* and *B. musculus*, none of these "finners" being planctonophagous, except perhaps occasionally. In fact the identity of the animal as differing from *B. borealis* was caused through a court-case about the fineness of this fringe which had been sold as that of the Seihval, the Norwegian name for *B. borealis*. The asymmetry of skeletons of Cetacea is extremely great—not so great, however, as to allow of such disparity of form of the breast-bone between *B. borealis* and *B. brydei*, as shown in the illustration, which is, I believe, noted here for the first time.

This Bryde's Whale frequents our coast for a much longer period than any of the others. Its partiality for a fish diet may induce it to remain here for, it may be, the whole year. It has not been noted in the Antarctic, nor, do I believe, has it been met near the Equator.

(5) *Balaenoptera acuto-rostrata*, Lesser Fin-Whale, or Pike-Whale of the English, and Minkehval of the Norwegian. The identity of the species of this name occurring in the northern waters of Europe and America with that of the animal found south as far as lat. 70 S. is still doubtful. Liouville (Charcot's Expedition) has not met with it. Racovitza (Belgica Expedition) has seen it twice, but has not noticed the white band on the pectoral fin—a most noticeable feature of the species. Kristensen and Klug (Antarctic Expedition) have seen one and captured another, but neither mentions the very striking band of the pectoral fin. In this case the stomach of the captured example was full of red shrimps (*Euphausia*). *B. acuto-rostrata* is eminently ichthyophagous. Lillie (Terra Nova Expedition) says, on the other hand: "When sailing in Antarctic waters to the

south of lat. 64° S. scarcely a day passed without our getting a sight of one of these whales." But is it *acuto-rostrata* or *bonaerensis* Burm.?

In the reference given by Lillie as to the identity of the animal I read that no example was secured. The identification is thus one of sight—at close quarters it is true. As to the evidence quoted by him by Norwegian whalers that the "Minkehval," which is their name for *B. acuto-rostrata*, is shot off the South Shetlands during the whaling season, I put little reliance upon it from my experience here with Norwegian whalers.

But the fact remains that on the shores of Table Bay was stranded four years ago an undoubted example of a 12-ft.-long juvenile *Balaenoptera acuto-rostrata* with the typical white band on the pectoral fin. The skeleton is now in the Museum.

With the evidence of the Antarctic I prefer to consider it as yet a roamer from the North.

Megaptera longimana, or *M. boops*, Hump-back Whale. We have in this animal a whale of quite different build and not reaching more than 50 ft., if ever so much. Liouville, however, mentions 58 ft. 6 in. The species is probably carcinophagous; some Cape examples have been found to be partly ichthyophagous. Incidentally the animal has an os-penis—a thing unknown among other whales.

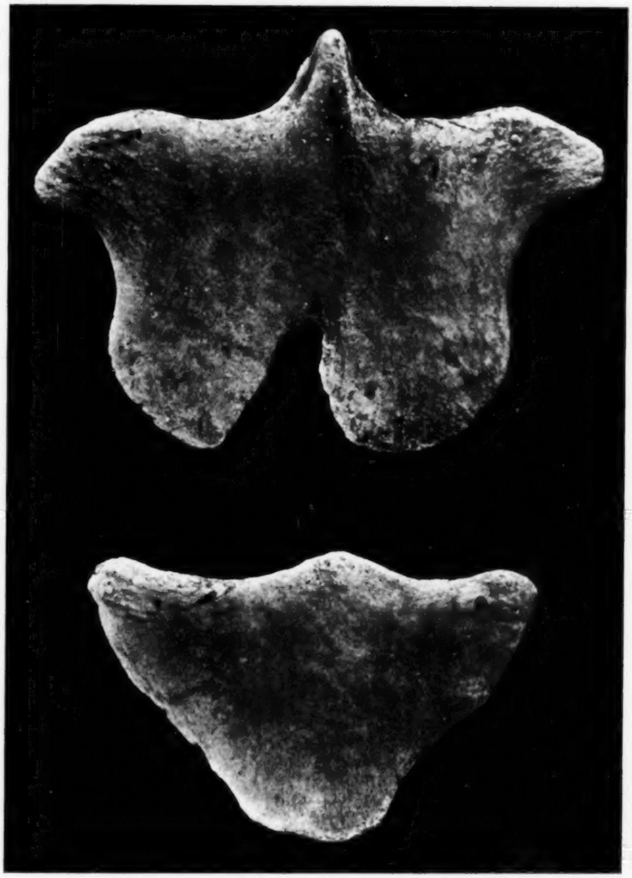
The fact is now well established according to my lights and observations that certain northern whales are specifically identical with the southern whales, and are the kinds of whales found on our coast. That they are migrants, perhaps with the exception of *B. brydei*, is a well-established fact, but what is probably less known is that the animals go to warmer equatorial waters to breed or calve. If they are intercepted on their way there from the Antarctic or on their return to the Antarctic, the multiplication of the species will be greatly hindered, to say the least.

At the present day the whaling industry in the South Polar Circle has attained such dimensions that unless checked or regulated one may well speculate on the time left for survival of the Hump-back, Blue Whale, Fin-Whale, Seihval and Bryde's Whale, etc., frequenting our waters. One vessel in the south, during the six months' whaling season, may capture more than 300 animals. The total number caught off South Georgia and the South Shetlands together is said to have exceeded 10,000 in one year. As stated before, the whales frequenting our coasts are travellers to or from the equatorial waters where they resort for calving; in each of the three species principally hunted in the south the pairing season is at its height when the whaling season is either slackening or not carried on, and that if these whales are to be protected during their breeding season on behalf of he future of the whaling industry it must be done further north than South Georgia. Even here the number of captured Hump-backs is almost negligible, as is admitted by all whaling people. Most of them ascribe the

fact to their having become more wary. Is it not more likely due to the fact of their destruction in large numbers in the south? In the first days of subantarctic whaling the Hump-back constituted nearly the whole catch, even more than 96 per cent. in 1910–11. It was reduced to 478—about 18 per cent.—in the same locality in 1913–14.

People interested here in the whaling industry admit that some measure of protection is necessary.

I.



II.

I.—*Balaenoptera borealis.*
II.—*Balaenoptera brydei.*

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NOTES ON SOME SOUTH AFRICAN ENTOMOPHTHORACEAE.

By S. H. Skaife.

(With Plates II—IV.)

The material on which the following notes are based was collected at Cedara, Natal, during the eight months August, 1919, to March, 1920. So far very few records of South African *Entomophthoraceae* have been published, the writings of Pole-Evans, Edington, Black and others on the locust fungus, *Empusa grylli*, being the only publications known to the present writer.

The family *Entomophthoraceae* belongs to the order *Entomophthorales* and includes some fifty or more described species, the great majority of which are parasitic on insects. Only one other family, the *Basidiobolaceae*, all of the members of which are saprophytic or parasitic on the higher fungi, is included in this order.

The two orders, *Entomophthorales* and *Mucorales*, together make up the sub-class *Zygomycetes* of the great class of alga-like fungi, the *Phycomycetes*. These two orders agree with one another in that all the species included in them have isogamous sexual spores, but the *Mucorales* are distinguished by having the conidia borne in sporangia, whereas in the *Entomophthorales* the conidia are borne singly and apically on club-shaped conidiophores.

The family *Entomophthoraceae* has been subdivided into several genera, but some of these are of doubtful rank. *Massospora*, Peck, is an aberrant genus that, so far as present knowledge goes, is restricted to North America; *Tarichium*, Cohn, no longer stands, as it seems to have been based on the resting stage of an *Empusa*; and Nowakowski's genus, *Lamia*, is not valid, according to Thaxter, as the species on which it was founded, *E. culicis*, is a typical *Empusa*.

We are thus left with two genera, *Empusa* and *Entomophthora*. Thaxter, in his classical monograph (1), recognises only the genus *Empusa*, and regards *Entomophthora* as a sub-genus, characterised by the compound, branched conidiophores. More recent writers, however, recognise both genera, the species in which rhizoids are present being classed as *Entomophthora*, and those in which rhizoids are absent being placed in the genus *Empusa* (2). In the present paper the latter classification is followed.

EMPUSA, Cohn.

Cystidia and rhizoids absent.
Conidiophores simple or branched.

Empusa muscae, Cohn. (Plate II, figs. 1–4.)

Conidia bell-shaped, with a broad, subtruncate base, 18–20 × 25–30 μ containing usually a single large oil-globule, and surrounded after discharge by a mass of protoplasm. Conidiophores simple, club-shaped, emerging in white rings between the segments of the abdomen of the host. Secondary conidia spherical, formed by direct budding from the primary conidia. Host attached to substratum by proboscis.

Hosts.—Muscid flies.

Habitat.—Cosmopolitan.

This is perhaps the commonest and most familiar of all the *Entomophthoraceae.* It was first noticed at Cedara on a large species of Anthomyid fly out-of-doors on August 17, 1919. A number of these flies were found dead in the garden on this date, fixed to foliage by their proboscis. The first house-fly killed by this fungus was found in the house on a window-pane on October 18. It was found to be common on house-flies at Umfolozi in Zululand in November. The disease was prevalent at Cedara until the first week in January, when it suddenly disappeared, no specimens dying of the disease being found after the 7th of this month, although house-flies were abundant and the weather damp and warm.

By collecting all the dead house-flies in the house each day and keeping a careful watch it was found that all the victims of the disease died in the evening, somewhere between 6 and 8 p.m. The following notes are typical of several records made:

"Specimen 1, 6.55 p.m.—Adhering to window-pane by its proboscis. When removed could still move its antennae and proboscis.

"7.5 p.m.—Slight twitchings of antennae only signs of life.

"7.10 p.m.—Quite dead.

"7.30 p.m.—Intersegmental membranes of the abdomen distended and gleaming white.

"9.30 p.m.—Protrusion of conidiophores well marked.

"10.15 p.m.—Large numbers of conidia have been thrown off.

"Specimen 2, 6.55 p.m.—This individual could buzz its wings and walk quite freely, but could not fly when found.

"7.10 p.m.—Can walk feebly.

"7.20 p.m.—Proboscis and antennae still retain power of movement.

"7.30 p.m.—Dead.

"10.15 p.m.—Conidiophores prominent.

"11 p.m.—A few conidia have been thrown off.

"Specimen 3, 6.55 p.m.—This individual was sluggish and easily captured, but could still fly.

"7.10 p.m.—Can no longer fly, but can walk freely.

"7.20 p.m.—Can cling tenaciously, but when turned on its back cannot right itself.

"7.55 p.m.—Dead.

"10.30 p.m.—Conidiophores prominent.

"No conidia given off yet."

Individuals which were still quite active, but which had distended, white abdomens, were found on dissection to have the abdomen filled with spherical, hyphal bodies of regular shape and size, measuring about 40 μ in diameter. Just as the host is on the point of death these hyphal bodies germinate and grow with extraordinary rapidity, giving rise to the conidiophores and in three to four hours producing conidia.

Although the house-fly fungus has been much studied in different parts of the world, the occurrence of resting spores has only been recorded once. Winter (3) states that they are spherical, colourless, and 30–50 μ in diameter. No resting spores were found by the present writer, although some dozens of specimens were examined and several attempts were made to induce the formation of these spores by placing infected flies in conditions unfavourable to the fungus. It was found quite easy to inhibit the formation of conidia by placing specimens, immediately after death, in tightly-corked glass tubes containing a little calcium chloride. Exposure of only an hour to this dry atmosphere served to arrest the development of the fungus inside the body of the host. No conidia were formed when several infected flies were placed together in a small tightly-corked tube, and submersion in water also served to prevent conidia formation. It was found that when once the development of the fungus had been checked in any of the above ways it failed to develop further, even when placed under the most favourable conditions. In the moist chamber the hyphal bodies broke down in the course of a few days, and in no cases were any signs of conjugation or the formation of resting spores seen.

Both sexes of the house-fly seem to be attacked impartially, and vigorous individuals seem just as liable to infection as those that are spent. Several dead females were found whose abdomens contained large numbers of eggs.

In 1912 Hesse (4) claimed to have succeeded in artificially cultivating *E. muscae*, and Bernstein (5) confirmed his results in 1914. No further work on this subject seems to have been done since the latter date. Hesse used as his culture medium the yolk of egg spread on glass slides and kept in a moist chamber. He states that he invariably obtained a profuse growth of the common mould *Mucor racemosus* from *Empusa* conidia sown on this medium. By feeding these *Mucor* spores back to adult house-flies he was able to produce epidemics of the disease at will.

The present writer repeated Hesse's experiments many times, but never once was a growth of *M. racemosus* obtained. From Bernstein's account of the experiments conducted by himself and Hesse it would seem that the initial cultures were obtained by placing the infected flies on the slides bearing the culture medium. He definitely states (p. 28) that "it was impossible to sterilize the flies from which the cultures were obtained." Obviously a grave source of error was introduced in this way. In order to overcome this the writer sterilised the flies used in the experiments by soaking them for fifteen minutes in a 1 per cent. solution of corrosive sublimate, the specimens being afterwards well washed in sterile water. The soaking was not long enough to prevent conidia formation provided the specimens were so treated immediately after death, yet it served to kill any foreign spores or bacteria adhering to the exterior of the flies.

Besides egg-yolk colostrum was also used as a culture medium, this being also a highly concentrated nutritive substance. The tubes containing the colostrum were sterilised in a slanting position, and in this manner excellent slopes of the coagulated milk were obtained. The infected flies, after sterilisation, were dropped into the tubes containing the egg-yolk and colostrum slopes, and next morning, after large numbers of conidia had been thrown off in each tube, the flies were removed. In no case was a growth of *M. racemosus* obtained. The conidia germinated freely and grew for two or three days, but no increase in bulk took place, and finally the germ tubes died and disintegrated.

A large number of flies that had not been sterilised were dropped into the tubes, and in many cases profuse fungous growths were obtained. These were found to consist of *Mucor, Rhizopus* and *Penicillium*, spp., besides other saprophytic fungi that were not identified, but in no instance was a growth of *M. racemosus* found in the cultures.

The *Mucor* spores obtained in the above cultures were mixed with a solution of sugar in water (as recommended by Hesse), and fed to fifty or more house-flies bred in the insectary and kept in a roomy cage. None of these flies died of *Empusa*, although in the house numbers of flies were dying of the disease at the time.

Empusa conglomerata, Sorokin. (Plate II, figs. 5 and 6.)

Conidia ovoid, usually with a single large oil-globule, $20–25\,\mu \times 25–40\,\mu$, average length about $35\,\mu$. Conidiophores simple. Secondary conidia like the primary, produced by direct budding. Resting spores not observed at Cedara, but according to Thaxter they are "azygospores, produced from spherical hyphal bodies, and borne on a neck-like process of variable length."

Host.—Imago of *Nephrotoma umbripennis*, Alex. (Tipulid).

Habitat.—South Africa, U.S.A., and Europe.

Only one specimen was found, the host clinging to a pine-needle by

means of its legs, on August 8. The above determination is based entirely on the shape and size of the conidia, which agree very closely with Thaxter's description and figure. Until the resting spores are observed, however, the determination must be regarded as somewhat doubtful, especially as Thaxter states that his specimens (Tipulid larvae and imagines) were found floating on water.

Empusa grylli, Fresenius. (Plate III, figs. 7–12.)

Conidia ovoid to pear-shaped, 25–45 $\mu \times$ 20–35 μ, average about 35 $\times$ 28 μ, containing one or more large oil-globules. Conidiophores simple, club-shaped. Secondary conidia like the primary and produced by direct budding. Resting spores spherical, colourless, very regular in shape and size, 30 μ in diameter, with thick, double, hyaline walls. Host attached to tips of grass, etc., by the contraction of its legs.

Hosts.—Orthoptera (according to Thaxter, also *Lepidoptera* and *Diptera*).

Habitat.—South Africa, U.S.A., Europe.

This disease was first noticed on grasshoppers on January 10 at Cedara. It was exceedingly common from this date until the end of March, attacking impartially several different species of Acridiids.

According to Sacharov (6) and Perez (7) this fungus only attacks spent adults, but at Cedara all stages from the second instar to the adult stage were found dead of the disease, and several dead females were found whose ovaries contained eggs.

As was noticed in the case of *E. muscae*, all the infected individuals that were kept under observation died in the afternoon, the great majority dying between 5 and 7 p.m. Sluggish individuals could be found in the field clinging to grass-stems at 1 p.m. Earlier in the day no dying individuals could be found. This remarkable characteristic of the fungus is probably explained by the climatic conditions at Cedara. During the summer the mornings are usually warm and dry, but in the afternoon mists and thunderstorms came up, making the atmosphere very moist.

During the period that this fungus was kept under observation about 1 per cent. of the individuals that were found infected failed to throw off conidia, even when kept under favourable conditions. On dissection these individuals were found to contain numerous resting spores (fig. 12). The mode of formation of these spores was not observed. Attempts to germinate them in water all failed, although hyphal bodies and conidia germinate quite freely in drops of water.

In view of Hesse's claims regarding *E. muscae*, it is interesting to recall the work of Edington and Black on the locust fungus, carried out at Grahamstown over twenty years ago. These two authors cultivated a fungus on a large scale, and this was distributed to farmers as the locust fungus. The reports of the efficiency of this fungus as a means of control

were conflicting, but several farmers announced excellent results from its use. In 1899 D. McAlpine, the plant pathologist of New South Wales, secured some of the cultures and pronounced the fungus to be *M. racemosus*, Fres. (9)—that is to say, the same fungus that Hesse claims to have secured from artificial cultures of the house-fly fungus.

Lounsbury sent some of the cultures to Kew in 1900, and Massee (10) states that they consisted of pure cultures of a new species of *Mucor*, which he named *M. etiosus*. In his paper describing this species he gives some interesting details of some experiments he carried out with the fungus on *Periplaneta australasiae*. Cockroaches which were sprinkled with the spores or which were made to ingest them died within twenty-four hours. Unfortunately Massee does not state whether he obtained a typical growth of *E. grylli* on the dead insects or not.

Cultures of the South African locust fungus (so called) were tried on a large scale in the United States in 1900 (11), and once again conflicting reports of its utility were obtained. On the other hand, Stockman (12) definitely states that the *Mucor* proved useless against locusts in India.

The writer repeatedly tried to cultivate *E. grylli* artificially, using the methods and media described under *E. musca*. In no case was a growth of *M. racemosus* or *M. etiosus* obtained. Fresh conidia, hyphal bodies and resting spores were used in these attempts, but only the first two germinated, and even these failed to grow in the real sense of the word, as no increase in bulk took place.

Abundant growths of two or three undetermined species of *Mucor* and of a species of *Rhizopus* were obtained by freely exposing bread-paste and potato-slices to the air. The spores of these saprophytic fungi were spread over slices of carrot and fed to cockroaches of an undetermined species that were common under stones at Cedara. These insects flourished in captivity, and none died during the three weeks they were kept under observation, although they must all have swallowed myriads of spores in this time. Similarly individuals that were liberally sprinkled with spores failed to become infected, although kept in a damp atmosphere. On the other hand, out of five nymphs that were inoculated with the spores suspended in sterile water, four died within three days, and all were found after death to contain ovoid and spherical bodies. These bodies were very numerous, some occurring singly, but the majority being in chains, and they were apparently the cause of death in each case. As a very similar growth was obtained in several instances from *Mucor* spores grown in hanging drops of nutrient solutions, it seems legitimate to conclude that the cockroaches in this experiment were killed by the *Mucor* spores injected into them. None of the five individuals in the control experiment that were inoculated with sterile water died.

The experiments carried out by the present writer failed to confirm the

results obtained by Edington, Black, Hesse, and Bernstein, yet it seems safest to reserve judgment in the matter, for it is a remarkable fact that these workers, experimenting with two different species of fungi in widely separated localities, should have obtained such similar results. Mycologists may find it very difficult to accept the theory that an *Empusa* becomes a *Mucor* when grown saprophytically, but the two orders to which these species belong are nearly allied, and similar cases of alternation of generations are familiar to all biologists. Furthermore, it is of interest to note in this connection that the torula form of *Mucor* bears a marked resemblance to the hyphal bodies that are characteristic of the *Entomophthoraceae.*

ENTOMOPHTHORA, Fresenius.

Cystidia and rhizoids present.
Conidiophores simple or branched.

Entomophthora aphidis, Hoffman. (Plate IV, figs. 13, 14.)

Conidia long ovoid, commonly asymmetrical, very variable, containing one to several oil-globules, 20–35 μ × 10–15 μ. Conidiophores simple or branched. Cystidia long and generally tapering at their extremities. Secondary conidia spherical, containing usually a single large oil-globule, produced by direct budding. Resting spores not seen at Cedara, but according to Fresenius and Sorokin they are "spherical, 33–45 μ, and borne terminally or laterally on hyphae." Host attached to substratum by rhizoids, few in number, and terminating in a disc-like expansion.

Hosts.—Several species of aphides.

Habitat.—South Africa, U.S.A., and Europe.

This species was first noticed at Cedara on November 11 on a species of large green aphis common on peas. It was common on certain species of aphides found on sweet peas, roses, maize, and *Datura stramonium* throughout the summer, serving as a very effective check on these pests. On the other hand, no specimens of the common cabbage aphis nor of a black aphis common on chrysanthemums were found infected with the disease.

The cystidia are not numerous, but are readily recognised by the fact that they are much longer than the conidiophores and contain very little protoplasm. Apparently they are hyphae, which would have developed into rhizoids if they had come into contact with the substratum. The rhizoids are long and comparatively stout, and lose their protoplasm soon after forming the disc-like expansion at the end.

Entomophthora apiculata, Thaxter. (Plate IV, figs. 15, 16.)

Conidia spherical, with a prominent papillate base, from 30–45 μ in diameter. Conidiophores simple. Secondary conidia like the primary, produced by direct budding. Resting spores were not seen at Cedara, but

according to Thaxter they "are formed laterally or terminally from hyphae, spherical, hyaline, 30–45 μ." Host attached to substratum by long and conspicuous rhizoids, few in number, and terminating in a disc-like expansion.

Hosts.—*Lepidoptera*, imagines of *Lycophotia muscosa*, Geyer (Noctuid), of an undetermined Geometrid, and a Lycaenid; larvæ of *Pachypasa capensis*. *Diptera*, imagines of a large Anthomyid fly, and of *Nephrotoma unicingulata*, Alex.; *Coleoptera*, imagines of *Trocalus fulgidus*, Fabr., and of *Adoretus ictericus*, Burm.; *Hemiptera*, adults of *Locris arithmetica*.

Habitat.—South Africa and U.S.A.

This species was exceedingly common at Cedara during the latter half of the summer, the first example of it being found on a larva of *Pachypasa capensis* on December 22. During the months of February and March it caused the death of large numbers of the beetles named above, the victims being found mostly on the trunks of wattle trees, fixed by means of rhizoids, with their wings partially spread.

The Cercopid, *Locris arithmetica*, is exceedingly common on grasses at Cedara during the summer months, yet only two individuals were found killed by this fungus. Both specimens were fixed to grass stems by means of rhizoids, and both had their wings outspread.

The fact that various species of hemipterous insects are liable to attack by *Entomophthoraceae* indicates that the host is infected by contact with the conidia, and not by their ingestion, as maintained by Hesse and others. It is difficult to understand how insects which are provided with mouth-parts such as those found in the *Hemiptera* and which feed on the sap of plants could swallow the comparatively large conidia of these fungi.

Entomophthora megasperma, Cohn. (Plate IV, figs. 17, 18.)

Conidia long ovoid, of irregular shape, with bluntly rounded apex and base, containing numerous small oil-globules, 10–20 μ × 15–35 μ. Conidiophores simple or branched. Cystidia not observed. Secondary conidia like the primary and produced by direct budding. Resting spores spherical, 35–40 μ in diameter, with thick, opaque, dark-brown epispore, borne laterally or terminally on the hyphae. Host fixed to substratum by rhizoids.

Hosts.—Larvae of *Euxoa segetis*, Schiff.

Habitat.—South Africa, U.S.A., and Europe.

In 1875 Cohn described a new parasitic fungus found in the larvae of *Agrotis segetum*, which he named *Tarichium megaspermum*. Only the resting spores were found, and Cohn's description of these agrees with that given above. Thaxter, in his monograph, describes a new species which he found on the larvae of *Agrotis fennica* and names it *E. virescens*. In this case only the conidial form was observed.

At Cedara an *Entomophthora* was found to be common on cutworms from October to January. It occurred in two forms; in the one conidia were thrown off in the usual manner, whilst in the other no conidia were formed, but the body of the host became filled with blackish brown resting spores. In both cases the hosts were fixed to the upper sides of leaves, etc., by means of rhizoids, but in the latter case the victim's body was blackened and flattened on to the substratum. There could be no doubt but that the two forms belonged to the same species of fungus. They occurred simultaneously on similar hosts, in each case the rhizoids were exactly similar, and in the bodies of cutworms containing the resting spores the remains of typical hyphal bodies could be found.

Thaxter expresses the belief that *E. virescens* and *T. megaspermum* are identical, but could not be sure, as he never found the resting spores. Both forms were found side by side at Cedara, although no specimens were found which bore resting spores and conidia simultaneously. Apparently the fungus exhausts itself in producing either one or the other form of reproductive body, but not both.

If these two forms do both belong to the same species—and every indication points that way—then Thaxter's name *E. virescens* falls before Cohn's *megaspermum* and the species becomes *E. megasperma*. According to Burger and Swain (12) *E. chromaphidis* also produces resting spores very similar to the above, and no individuals were found bearing both conidia and resting spores at the same time.

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EXPLANATION OF PLATES II—IV.

PLATE II.

Fig.		
1.	*Empusa muscae*, Cohn.	Hyphal bodies from a still active fly.
2.	" " "	Hyphal bodies immediately after death of host.
3.	" " "	Hyphae from abdomen during conidia formation.
4.	" " "	Conidia, showing mass of protoplasm surrounding each. Two conidia forming secondary conidia.
5.	*E. conglomerata*, Sorokin.	Conidia, one forming secondary conidium.
6.	" "	Resting spores (copied from Thax).

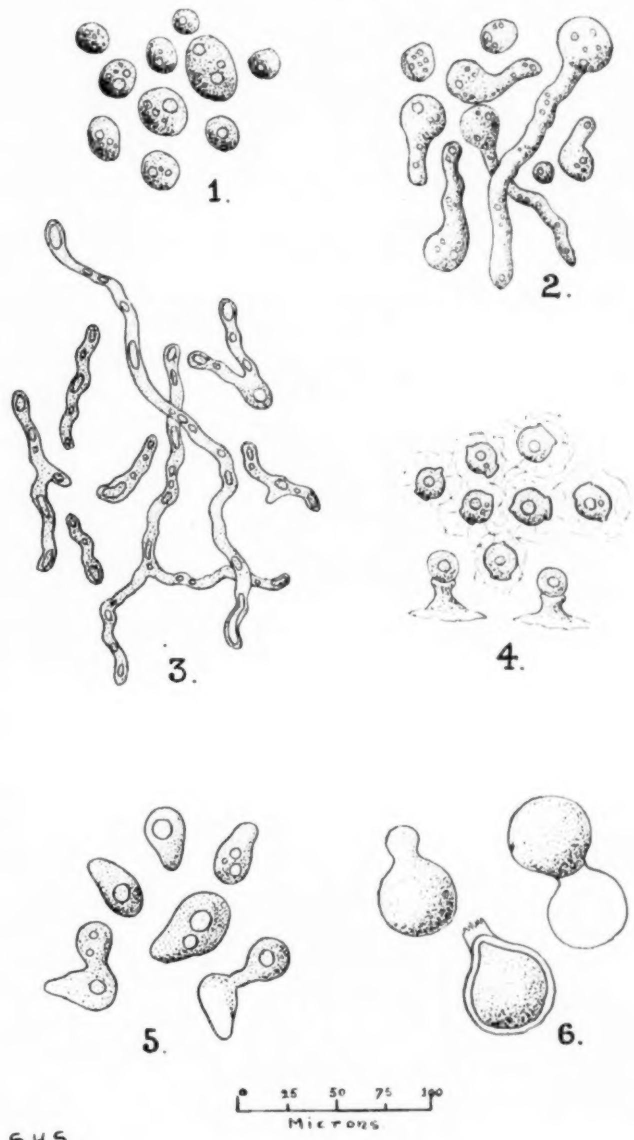
PLATE III.

7.	*E. grylli*, Fresenius.	Hyphal bodies from living grasshopper.
8.	" "	Hyphal bodies immediately after death of host.
9.	" "	Internal hyphae during conidia formation.
10.	" "	Conidia, some forming secondary conidia.
11.	" "	Conidiophores.
12.	" "	Resting spores.

PLATE IV.

13.	*Entomophthora aphidis*, Hoffman.	Conidia and secondary conidia.
14.	" " "	Cystidia and rhizoids.
15.	*E. apiculata*, Thaxter.	Conidia.
16.	" "	Rhizoid.
17.	*E. megasperma*, Cohn.	Conidia.
18.	" "	Resting spores and one of the peculiar empty hyphae that often accompany them.

All figures, with the exception of No. 6, redrawn from camera lucida drawings. × 500.



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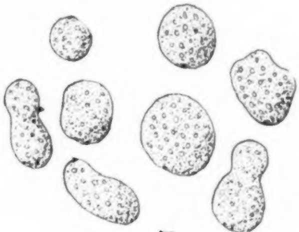

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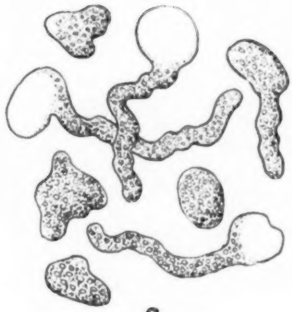

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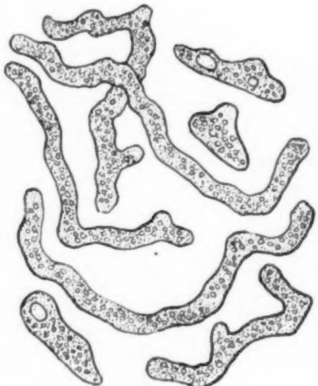

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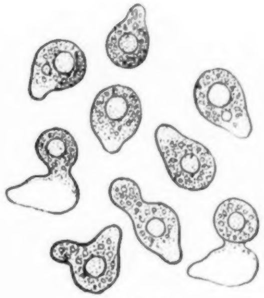

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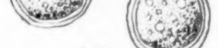

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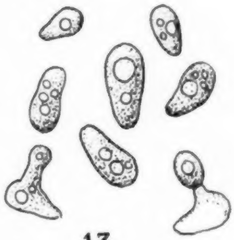

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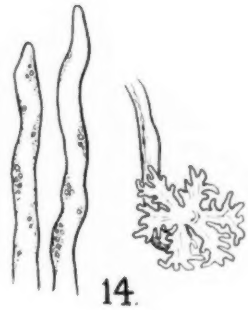

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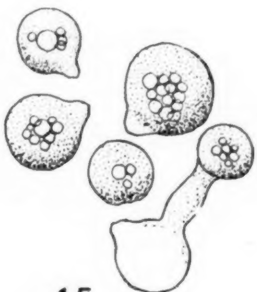

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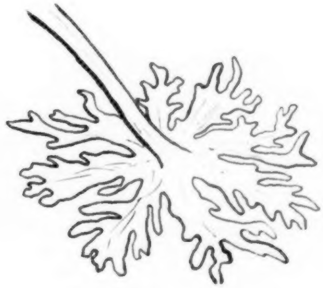

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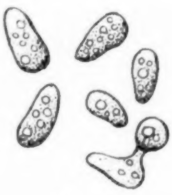

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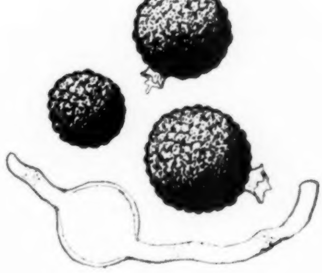

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OVERGROWTHS ON DIAMOND.

By J. R. Sutton.

The Affinity between Diamond and Carbonate of Lime.

"Formerly the diamonds were picked out from the concentrates by means of the keen eyes of skilled natives, but the process has been vastly simplified . . . by the remarkable discovery made in 1897 by F. Kirsten of the De Beers Company, that of all the heavy constituents of the blue ground, diamond alone, with the exception of an occasional corundum and zircon, which are easily sorted out afterwards, adheres to grease more readily than to water. In this ingenious machine . . . the concentrates are washed over a series of galvanised-iron trays, which are covered with a thick coat of grease. The trays are slightly inclined downwards, and are kept by machinery in constant sideways motion backwards and forwards. So accurate is the working of this device that few diamonds succeed in getting beyond the first tray, and none progress as far as the third."

This account, which contains nearly all that is necessary by way of preface, is extracted from G. Herbert Smith's charming 'Gem Stones,' 1912, p. 148. Evidently the secret of the process, as Lawn has said, is surface tension. Common minerals can easily be wetted, whereas diamond cannot be; and because of the wetting the grease cannot touch the mineral surface, whereas it can touch the dry diamond.

According to G. F. Williams "only about one-third of 1 per cent. of diamonds is lost by the first table, and these are recovered almost to a stone when the concentrates are passed over the second table." ('The Diamond Mines of South Africa,' 1902, p. 380.)

J. Stewart reports further that for the six months July to December, 1909, out of 1,211,552 carats of diamonds recovered at the De Beers Company's pulsator all but 1,249 carats were caught on the first tables—an efficiency of 99·9 per cent.

But it is a curious fact that while diamonds of all kinds, including bort, from the blue ground adhere readily to the grease tables, those from the surface yellow ground are much less easily caught. Some years ago a

parcel of diamonds from the Wesselton Mine yellow ground was handed to me for examination. Some concentrates from the yellow ground had been passed over the grease tables with the following result:

	Carats caught.	Per cent.
First table	241	50·52
Second table	90	18·87
Third table, and final dry sorting of rejected concentrates	146	30·61
	477	100·00

That is to say, instead of a loss of between one-tenth and one-third per cent. (the values quoted above), only about a half of the diamonds were caught on the first table—a result scarcely better than an electrostatic separator would give. Clearly it was lucky that the grease tables were not thought of in the early days of Kimberley when nothing but yellow ground was being worked, for, had they been tried then, that excellent invention would probably have passed stillborn into oblivion.

In the matter of the anomalous behaviour of the yellow-ground diamonds the problem to be solved was unique inasmuch as there was no outside analogy for a guide. To begin with, there was nothing to show whether the surface of yellow-ground diamond was essentially different from that of blue-ground diamond, or whether the anomaly arose from some disturbing factor in the matrix. As to the former alternative, there was a prevalent belief that the surfaces of diamonds found in the early days of Kimberley were on the whole more brilliant than those obtained later, in the deep workings. As to the latter alternative, it appears that the soapy-feeling substance lining the blue-ground matrix of diamond has not quite the same constitution as adjacent blue-ground has. This point will be referred to again.

The first step in the attempt to solve the problem was made by screening the diamonds caught on the three different tables into series of sizes. From the results it was ascertained that, generally speaking, the larger diamonds tended to adhere to the grease on the first table better than the smaller ones did, those caught on the third table not often exceeding a quarter of a carat each. There was, moreover, a marked difference in the behaviour of the smaller diamonds with respect to the tables, for while those caught on the third table, or dry sorted afterwards, were largely of good shape with no specially great proportion of cleavages and splinters, those caught on the first table were mostly irregular or broken pieces. Hence it seems that a still larger quantity would have been lost by the first table if the normally great percentage of Wesselton cleavage were less. Two possibilities were thus suggested:

(1) The larger diamonds stick better than the smaller ones do because

their weights being great relatively to their surfaces they travel more slowly in a given current of water, and so can sink mechanically more heavily into the grease. Here it may be noted that pieces of iron and heavy minerals sink into the grease not because of any attribute of surface tension, but because the current of water flowing over the tables is insufficient to overcome gravitation.

(2) Apart from that, some peculiarity of surface seemed to be involved whereby fractured faces were more adhesive than natural faces. On the other hand the sharp edges of the fractured faces can plunge mechanically into the grease with more facility than natural edges can.

Under magnification, however, no characteristic difference could be detected either between the surfaces of the diamonds taken from the different tables, or between the surfaces of the non-adhesive yellow-ground diamonds and the surfaces of ordinary adhesive blue-ground diamonds. Some specific gravity tests, also, reveal no differences worth mention.

Since only a few diamonds from the blue ground are normally lost by the first grease tables, it remained to examine typical specimens of blue and of yellow ground in order to determine whether any accountable peculiarities exist in the respective matrices which might be communicated to a diamond surface. Competent geologists are pretty unanimous that "the yellow ground, which may go down even to 70 ft., is simply blue ground in a weathered condition, and contains the same minerals in due proportion." (W. H. Penning, 'Gold and Diamonds,' 1901, p. 4.) But unanimity in the case of the diamond is never evidence, and, for the most part, judging by the strong family likeness of the various accounts, each high expert quotes without question from some higher expert. At any rate some samples of blue ground, yellow ground and so-called "limestone" from the original overburden, were obtained for testing purposes from the Wesselton mining area. So far as could be seen the samples of yellow ground were typical and clean. The blue ground had other matter mixed with it, which had probably been scraped up from the depositing floors by the shovel. It could only be guessed whether the "limestone" was an average sample of its kind. It was a spongy-looking stuff of rather low specific gravity (? altered blue ground, or dolomitic), and to casual inspection carried particles of yellow ground. Portions of each of the three kinds of ground were crushed, gently dried, weighed, treated with dilute acid, evaporated to dryness, and again weighed, with the following result:

	Weight before treatment.	Weight after treatment.	Loss. Per cent.
Blue	10·000	9·225	7·75
Yellow	10·000	8·650	13·50
"Limestone"	10·000	9·975	0·25

In the acid the blue ground effervesced strongly, the yellow ground violently, the limestone scarcely at all. A sample of hard blue from De Beers Mine, tested at the same time, gave scarcely any effervescence, while some lumps of hard and soft limestone from Kenilworth effervesced violently, leaving no great proportion of insoluble residue, so that the effervescence of the blue ground may have arisen, at any rate in part, from an admixture of a foreign carbonate. Moreover, the substance (alluded to above) lining the matrices of sundry blue-ground diamonds effervesced very little.

These rough tests seemed to supply a clue worth following towards a solution of the problem. There is more carbonate of lime in yellow ground than there is in blue ground, and the question is, Will it, when it is plentiful enough, spread itself on a diamond surface in a crust capable of being wetted? Numerous experiments were accordingly made in the hope that premised feasible natural processes might to some extent be imitated in forming such a crust. Pastes were made of the blue ground, the yellow ground and the limestone, with hot and with cold water, in which small diamonds that had adhered normally to the first grease table were enclosed for some days. Sometimes these pastes were kept wet throughout, sometimes they were dried in gentle heat, and sometimes left to dry of themselves. Finally the enclosed diamonds were taken out and run over the grease tables at the pulsator. The results were only so far encouraging that neither the diamonds from the yellow paste nor those from the limestone paste showed any particularly marked inclination to stick to the grease. But, on the other hand, curiously enough, neither did the diamonds from the blue paste. Thus although all were originally normal first table captures, the act of putting them into the different pastes had for the most part destroyed their adhesive property.

Of course, only a soft and easily removable crust, at the best, can be deposited on diamonds by enclosing them for short periods in pastes of this kind. One effort was made to deposit a harder crust on four first table diamonds of about six carats each by placing them in four separate vessels with some blue, yellow, and lime ground respectively, well stirred with plenty of water, and leaving the water to evaporate slowly. This is a lengthy process, and was only partially successful. Scarcely any blue ground appeared to have attached itself to the diamond surface, though the lime and yellow were deposited in patches with some freedom. Upon roughly testing these diamonds for surface tension in water, it was found that those from the lime and yellow grounds gave much higher values per unit area of surface than those from the blue ground did, albeit a single test of this kind cannot be regarded as of much consequence. These same diamonds were afterwards passed over the grease tables: three adhered, and one, which had a fair coating of lime, rolled away.

The experiments were repeated with three good samples of virgin blue, yellow, and real limestone crust, obtained from the Kamfersdam Mine. In acid the blue gave no effervescence to speak of, while the yellow effervesced strongly, losing 20 per cent. of its weight, and the lime crust violently, losing fully 60 per cent. Pastes were now made as before of the virgin blue and of the lime crust in equal quantities, and ten first table diamonds, weighing on an average about a carat a-piece, were placed in each paste. The two lots of diamonds were chosen so as to be as nearly alike as possible. After the pastes had become quite dry they were broken, the diamonds were carefully extracted, soaked in water, and passed over the grease tables. Every diamond from the limestone paste rolled off as fast as the water could carry it; whereas nearly all the diamonds from the blue were caught.

Lastly, some third table and dry sorted diamonds, *i. e.*, diamonds which originally were not easily caught, or even not caught at all, by the grease, adhered quite well after having been cleaned in acid.

Reasoning from the above results, the following conclusions, *venio rogatum*, would seem to be justifiable:

Yellow ground contains more calcite than blue ground does.

Calcic carbonate in suspension, or solution, deposits itself readily in thin layers on a diamond surface, causing that surface to approximate to the consistency of the common minerals in the pulsator concentrates.

This deposit being more easily wetted than a bare diamond surface is, the surface tension in water is increased, and that in grease decreased accordingly. Hence the coated diamond behaves like an equal mass of limestone on the grease tables.

The above account is drawn with no material alteration from my report made at the time some years ago. This report had been put away and the details half forgotten, although the conclusions were alluded to in a recently published paper. But during the last few months the results appear to have received some extraneous confirmation perhaps sufficiently important to warrant the publication of them. This latter development will now be briefly described.

Now, it is to be noted that if calcite, or limestone, can be made to form a crust on a diamond by artificial means, it ought to do the same naturally, in propitious circumstances. So far as the Wesselton yellow-ground diamonds are concerned, since they do not always adhere readily to the grease tables, this would appear to have been proved, or at least made probable, by the experiments described above. But since calcite occurs in fair abundance in some specimens of blue ground, there ought to be cases here and there in which blue-ground diamonds had acquired a calcite coating. The chances would be, however, that even so it would not follow that the coating would survive the rough treatment of mining and winning to the

end at the grease tables. Moreover, should it be a thick coating and completely enclose a diamond, and survive intact, the diamond would certainly be rejected by the grease tables like the superfluous concentrates; or, in case of dry sorting, probably rejected as a valueless piece of white mineral. The chances are therefore not altogether favourable for the detection of a diamond with a thick coating. Nevertheless diamonds heavily coated with a more or less complete shell are occasionally found. They come mostly from the interesting Bultfontein Mine, doubtless partly because the prevailing striated surface of Bultfontein diamond holds the coating best, and partly because of the abundance of calcite there; but they are found occasionally at Wesselton and Dutoitspan.

A significant fact about these particular lime-coated diamonds from blue ground is that the coating is not aragonite. For when it is boiled with cobalt nitrate it remains uncoloured. It is evident, therefore, that the coating was acquired at a late stage in the history of the matrix, and at a low temperature.

Equally significant is the fact that calcite is not found inside cracked diamonds from the Kimberley area. The filling material has been taken from the cracks of many diamonds on the De Beers sorting tables and in no case has it been calcite. Usually it appears to be apophyllite,* and pectolite has been found. Hence it may reasonably be inferred that the cracking of the diamonds took place at a relatively early period, and that the cracks became filled with a zeolite, or something of that sort, before the calcite was introduced, or separated out, into the matrix.† Which is yet another argument against the popular delusion that cleavages among diamonds are due to explosion after the diamonds are taken from their matrix.

Occasional Dutoitspan rounded yellow diamonds are reported which have failed to adhere to the grease tables. They carry no obvious foreign coating any more than the Wesselton yellow-ground diamonds did, but presumably they carry a coating even though it be indefinitely thin. And it may be surmised that they come from the vicinity of local accumulations of calcite in the pipe rock? One typical specimen that had been rejected by all three tables adhered to the grease quite normally after immersion in a weak acid.

It may be of interest to quote here some remarks made by Boutan in his great work 'Le Diamant,' 1886, p. 171. Speaking from actual experience of Kimberley as it was somewhere about 1884—*i. e.* at a time when the blue ground had been reached and was being worked, he says of the diamond:

"Il se présente sous bien des états divers de cristallisation, de couleur

* *Cf.* 'The Diamond Mines of South Africa,' p. 507.

† *Cf.* F. P. Mennell, 'The Miner's Guide,' 1909, p. 147; also P. A. Wagner, 'The Diamond Fields of Southern Africa,' 1914, p. 75.

et de grosseur; mais il est presque toujours enveloppé d'une mince pellicule calcaire, qu'on enlève avec les autres impuretés qui pourraient ternir sa surface en le laissant pendant quelque temps dans de l'acide azotique bouillant."

It is a curious statement to make, however, that diamonds fresh from the mine were almost always encased in a chalky envelope.* Certainly diamonds have always been put into acid—mostly aqua regia earlier, though hydrofluoric nowadays—before being sorted for shipment to London; but, as one understood, rather to remove impurities from cracks than especially to clean their surfaces, though of course it would do that too. And yet one hesitates to question the word of so careful a writer as Boutan. Possibly the explanation of the difficulty is either that such diamonds as he had the opportunity of seeing were thus coated, or that he mistook the main purpose for which the acid was generally used. True or not, the copyists lost a chance in not repeating the statement and so passing it on by their unanimity to the realm of historical fact. It may be mentioned here that it is well known at the De Beers pulsator that diamonds which have been lying for many years in the blue ground on the depositing floors are very intractable on the grease tables. Probably the long-continued weathering has set calcite free, either from the blue ground itself or from the limestone underlying the floors, to form an incrustation on the diamond.

A clean diamond is not readily wetted by ordinary rain or river water. If it be immersed in such water it will come out dry saving where droplets can cling to irregularities upon its surface, and even these are easily shaken off. A triangular flake of diamond whose edges are 12 mm. and whose thickness is 1·25 mm. will float indefinitely upon a still-water surface. If the same flake be placed edge downwards in the water whose depth is about 6 mm., the lower edge will rest at the bottom of the water and the top corner will project slantwise through the surface, and remain so, provided that the surface is kept fairly quiet. This is the largest thin flake there has been the opportunity to try, though doubtless much larger ones would behave in the same way. Small diamonds of good geometrical form up to at least 0·1 carat each will float on water, even when it is gently agitated, like corks, partly because of the surface tension of the water, but chiefly because they are not readily wetted, whereas most common minerals of the same size will submerge at once.

A number of simple experiments have been made with the object of ascertaining whether the addition of freely soluble substances to water would modify the surface tension between diamond and water. Saturated solutions of the following compounds showed no appreciable difference:

* *Cf.* G. F. Williams, p. 208: "All the crystals in the blue ground were encased in a smooth bed of the same material which did not adhere to the diamonds, so that their lustre, when extracted, was quite bright or glassy."

Alum, Epsom salts, sal ammoniac, common salt, saltpetre. Saturated solutions of the following increased the tension somewhat: Chloride of lime, borax, hyposulphite of soda. On the other hand, a solution of caustic soda wetted the diamond thoroughly. But of all the substances tried carbonate of soda proved by far the most effective. A diamond (crystal or bort) dipped into a saturated solution of carbonate of soda comes out wet and dries with a thick deposit of the substance. Even here, however, the wetting tends to be to a certain extent selective. The deposit as a rule dries thicker on the faces of the octahedron than it does on the edges; and, by the same token, thicker on the edges of the rhombic dodecahedron than it does on the faces. Some octahedra dry with their faces thickly coated (saving where deep triangular indentations interfere) and their edges scarcely dimmed, and some dodecahedra dry with their edges sharply outlined in white. This result may arise from faulty manipulation, or it may have been accidental to the limited number of stones treated; but it is curious that the observer occasionally comes across a diamond naturally coated on its octahedron faces with a black adamantine incrustation, while its edges are so clear that the colourless interior can be seen through them. On the other hand a bort incrustation favours the dodecahedron faces of Wesselton "black" (nearly opaque) diamond.

One other, minor, point: If a diamond be placed in a solution of carbonate of soda contained in a glass vessel, the soda, in spite of its affinity for the diamond, will crystallise out, as the water evaporates, by preference on the sides of the vessel above the water surface, while the diamond remains uncovered in the solution. But in a solution of cane-sugar crystallisation will begin on the diamond alone, and the latter after a time will appear as if enveloped in an extensive cloudy condensation. The reasons need not detain us.

Coated Diamonds: Some Observations and Inferences.

Diamonds with a black incrustation are common, especially at Wesselton. In the mines of the Kimberley area this incrustation is usually very thin, and under magnification is seen to consist of minute dull black specks more or less uniformly streaked over a somewhat rough and pitted surface—so thin indeed as to make the diamond look slaty-grey by reflected light and smoky-brown by transmitted light. Not improbably this coating is allied to the frequent black spots included in the body of spotted stones. Whether, so far as the Kimberley mines are concerned, it represents the remains of a thicker coating which has been lost either naturally or in the process of mining and winning is doubtful. Mr. P. Ross Frames, however, has obtained, at the Premier Mine, Pretoria, a small diamond from the midst of a lump of graphite, and at this mine diamonds with quite a thick, soft

black coating are sometimes found.* The black coatings of the Kimberley area diamonds may be amorphous or crystalline diamond, or even graphite like the Premier ones. It may be due to a temporary increase of temperature in past time. But a sufficiently great general increase of temperature is not very likely, if only for the fact that diamonds are found in intimate association with crystal garnet and coloured zircon. Of bort the same may be said; and quite recently a lump of stewartite containing numerous grains of almandine garnet was found at Bultfontein. High temperatures would be expected to render the garnet vitreous and to blanch the zircon.

The black incrustation is more likely to be a late corrosive sort of deposit on the diamond, quite independent of the process of crystallisation and not defining its final phase. And this view is supported by a small broken lump found at Koffyfontein which at first sight resembles a fragment of coal, but on closer examination proves to be transparent diamond thickly incrusted with a very hard black adamantine coat. It cannot be denied that the fracture preceded the incrustation.

This Koffyfontein specimen, then, helps us to see that the black spots common in diamonds have not necessarily always been enclosed within rapidly and continuously crystallising diamonds; and still less are these same spots centres of crystallisation in a metastable medium, but rather are incrustations on temporarily quiescent diamond surfaces analagous to the lime coatings dealt with above. For, suppose some black incrustation to form spots on a diamond crystal, then a further stage of diamond crystallisation would determine the black spots as inclusions like other minerals, such as garnet, pyrites, etc., captured in the same way. And this no doubt explains the frequent colour effects in their vicinity revealed by the polariscope. Also it helps us to see that Dutoitspan rounded yellow diamonds, which are much less subject to strain and are less spotted than most other kinds, were probably formed more rapidly in one continuous process.

Haüy, indeed, attributed the rounded form of some diamonds to rapid crystallisation:

"Mais la formation du diamant ayant été précipitée, les faces ont subi des arrondissemens, comme cela arrive par rapport à une multitude de minéraux" ('Traité de Minéralogie,' 1801, iii, p. 290).†

Whole stones incrusted in precisely the same way are met with now and

* See P. A. Wagner, "Note on Graphite-coated Diamonds from the Premier Mine," 'Trans. Geol. Soc. S.A.,' 1914; also 'The Diamond Fields of Southern Africa,' p. 143.

† Antonio Magliabechi expressed the opinion that diamonds do not grow larger by lying in the earth, but that their magnitude and figure are assumed at once (see 'Phil. Trans.,' No. 311, 1707). Leuwenhoeck gives reasons for thinking differently (*ibid.*, No. 324, 1709). But crystallisation, fast or slow, necessarily postulates a solvent.

again in the mines of Griqualand West. More important still, incrusted stones have been proved to exist inside larger ones. A good and typical instance was a Dutoitspan fragment of about two carats consisting of about a third of a whole white rounded diamond. Portions had split away from the original whole stone along two octahedral planes of cleavage, showing near the middle of the edge where the cleavage planes met a heavily incrusted little stone of fair form, as depicted on an enlarged scale in the annexed Fig. 1. The incrustation was at least as hard as ordinary diamond. Observed through what was left of the natural face the inside of the fragment appeared to be extensively blurred with large black blotches

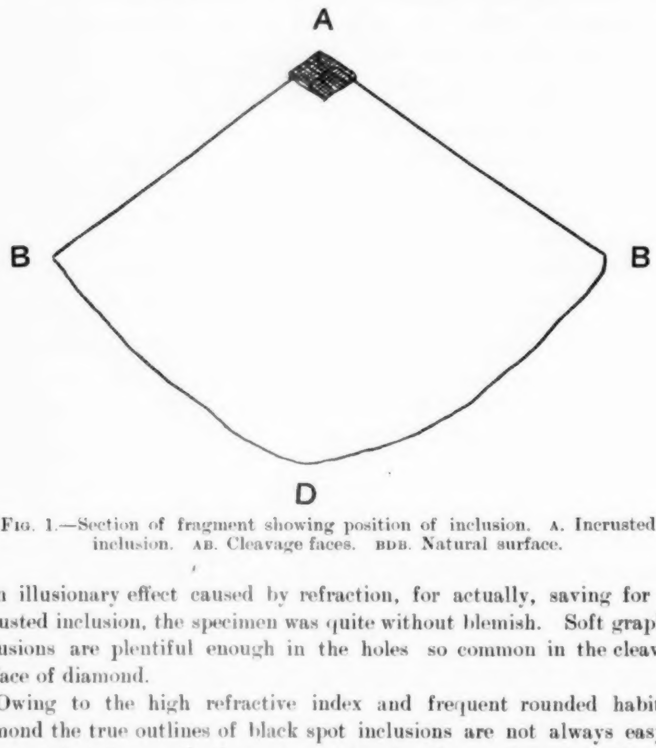

FIG. 1.—Section of fragment showing position of inclusion. A. Incrusted inclusion. AB. Cleavage faces. BDB. Natural surface.

—an illusionary effect caused by refraction, for actually, saving for the incrusted inclusion, the specimen was quite without blemish. Soft graphite inclusions are plentiful enough in the holes so common in the cleavage surface of diamond.

Owing to the high refractive index and frequent rounded habit of diamond the true outlines of black spot inclusions are not always easy to make out, but frequently they seem to be shapeless. Sometimes they are mere flakes. They occur either singly or in groups. Jagersfontein diamonds are noted for the dense and solid appearance of their large black spots. At the other end of the scale of size are the smoky-brown clouds—the danger-signals of sensational literature, giving warning of impending

explosion!—clouds of tiny black discrete particles. One would like to understand how the internal black spots are aligned with respect to the space lattice, as to which there is a striking suggestion in the case of a coated Bultfontein " rounded octahedron," within which at a depth of about a millimetre (as determined roughly by the focussing distance) under one face were three separate constellations of tiny black spots all lying in one octahedral plane of cleavage.* These constellations of spots were of additional interest because of the gorgeous chromatic display they gave under the polariscope, and also for their obvious relationship to the surface markings, for exactly over each constellation was a particularly well-defined indented triangle. Could the millimetre or so of the face have been cleared off, then without a doubt the new face would have had much the same sort of coated appearance as the existing natural face had.

I have observed the phenomenon of the superimposition of a deep indented triangle over a shallow-seated spot or spot area once or twice before, and thought that it could be explained as mere coincidence. The case of the above-mentioned Bultfontein stone nevertheless makes it pretty certain that spots may on occasion interrupt the orderly rate of crystallisation, and hence that they are not likely to be action centres of growth themselves.

It is quite on the cards that a competent study of the black incrustation and the black spots may yet explain a great deal that is yet unknown about the diamond macle and so justify the use of the name. For the majority of macles are spotted—some in the composition plane—as it is not quite accurately termed, seeing that the seam is not as a rule a plane at all—others in most remarkable streaks along the grain, and yet others in both ways together. The streaks running along the grain—*i.e.* in the dodecahedral cleavage planes—are very common in macles, and practically non-existent in simple crystals. Some macles display, indeed, saving for a comparatively clear space in their centres, almost as much streak as diamond. Granting, for argument, that the streaks are graphite, they show at least that macles must have grown in a more graphitic environment than simple crystals did. It is not meant by this that the graphite must have forced the macling, for many macles are quite free from streaks and spots too, but that the two sorts of conditions were unlike under which macles and simple crystals came into being, conditions perhaps in which the production of graphite was more favourable than it was elsewhere. In this connection we may observe that the blue grounds of the Premier and Jagersfontein Mines are reported to yield a large percentage of macles and much graphite.

Falling within the category of coated diamonds, though not in the

* *Cf.* two observations of a similar kind made by Des Cloizeaux, cited by Boutan, p. 55.

market sense, are the occasional irregular crystals upon whose surfaces thick coatings of a kind of grey bort have been deposited. This bort might to all appearance have been put on in the form of a wet paste, with a spatula, and then dried hard. Such specimens as have come to light have never been completely covered by the bort, although there are pieces of the bort which look as if they may have diamond within. This kind of bort overgrowth is not commonly found on a natural crystal face, but rather on what appear to be faces of arrested growth, say on surfaces of attachment, and may be material which has flowed into and filled the interstices between the diamonds of a cluster, at any rate it simulates that effect. A Dutoitspan flat diamond which was found recently had such a surface of attachment covered with bort, and on the surface of the bort, which was much pitted, there were numerous tiny black particles—whether of graphite or of amorphous black diamond could not be determined—filling the pits. The bort overgrowth here spoken of forms a link between common grey bort and the cement-like stuff of the next section, merging by insensible gradations from the one into the other.

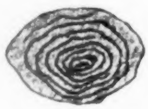

FIG. 2.—Hailstone structure of diamond. Surface of fracture showing alternate shells of diamond and grey cement.

THE HAILSTONE STRUCTURE.

Unequivocal proof that the crystallisation of diamond is by no means necessarily a rapid and continuous process is supplied by the diamonds which in a previous paper have been likened to hailstones.* Such diamonds are common enough, although they do not seem to have attracted much attention. Typically they consist of what looks like a kind of hardened and more or less porous paste, superficially not unlike Portland cement, alternating with layers or shells generally of curvilinear section (as sketched in Fig. 2) of clouded crystal diamond. Sometimes the core is diamond; now and then it is diamond with a small central spot of some cognate material; often it is an irregular lump of the cement alone so far as one can judge of its interior without breaking it open. When the outermost layer is cement the specimen is shapeless; when it is diamond it tends to a diamond contour—cube, octahedron, or dodecahedron—and it is usually

* "Some Controversial Notes on the Diamond," 'Trans. R.S.S.A.,' 1920, viii, p. 129.

much cracked. Naturally it is only in the broken specimens that the structure is revealed. The condition of the specimens indicates a higher co-efficient of expansion for the cement than for diamond; unless the cement is subject to secular shrinkage, which on various grounds is not altogether improbable. The colour of the cement varies from light to dark dirty-grey. It is much softer than diamond, writing a light grey streak on black amorphous bort. The denser pieces have a somewhat higher specific gravity than pure diamond; a lower specific gravity suggests porosity. Like diamond, the cement is insoluble in acids.

On account of the theoretical importance of these hailstone-like overgrowths I venture to attempt a description of some characteristic forms. The majority are from Bultfontein.

1. A broken piece showing an irregular core of light grey cement, surrounded by a thin shell of diamond, then a thin shell of cement, the whole enclosed in a thicker shell of diamond of irregular outline. Weight 4·5 carats.

2. An irregular lump showing no trace of crystal diamond. A crater-shaped hole in a projecting corner contains a tiny fragment of bright green mineral, probably chrome diopside. 0·5 carat.

3. A broken piece with a dark grey cement interior surrounded by a confused mixture of light grey cement and diamond. 0·7 carat.

4. A flat piece showing a centre of clouded crystal diamond surrounded by an inner ring of black crystalline diamond, and an outer ring of light grey cement. The original stone, of which this is a fragment, must have been roughly spherical. 0·5 carat.

5. A flat cleavage fragment showing a hexagonal flake of clouded and spotted diamond with an outer crystalline shell of a composition apparently intermediate between diamond and cement. This specimen is of further interest as showing dodecahedral cleavage with the dodecahedral striations. 1 carat.

6. A flat cleavage fragment in plan something like the section of a pear cut parallel to the stalk. This has a crystalline core surrounded by cement, then a thin crystalline shell, then a thicker shell of cement intersected by a portion of a very thin crystalline shell following the contour of the first for about a quarter of the way round its perimeter, and lastly, a crystalline casing. 0·2 carats.

7. A broken-off corner consisting of a black crystal interior surrounded by alternate shells of cement and diamond. Three more or less complete crystal shells and four cement ones may be counted. 0·2 carat.

8. A flat fragment consisting of a crystal central portion surrounded by four concentric shells of about 0·5 mm. thick, two of light-coloured cement and two of crystal. 3 carats.

9. A flat fragment broken from one end of what, to outside appearance, must once have looked like a cube of highly crystalline bort. A scraping of the broken face with a knife-blade indicates that it consists of numerous exceedingly thin successive overgrowths of bort and cement. 2 carats.

10. A somewhat hemispherical piece. The central crystal core is surrounded by no less than seventeen alternate concentric rings of light grey cement and black crystal diamond. 0·4 carat.

11. A pyramid consisting of a half of a "rounded octahedron." The edges, where dodecahedral striations would emerge on ordinary diamonds, are here of cement. Rather it looks like a piece of octahedral cement with projecting grey crystal bosses on the triangular faces, thus inclining the form to that of the plus and minus tetrahedral twin. 0·8 carat.

12. An irregular lump of cement to outside appearance. When first seen it was pitted with small elongated holes as though it had been prodded with the point of a penknife. At the time of writing it is scored over much of its surface with deep meandering cracks which either are (and look like) shrinkage cracks, or were there all the time, but hidden by being filled up with cement which afterwards fell out. 2·7 carats.

13. A fragment similar to No. 10, excepting that it has rather fewer shells, has an outer coat of shiny bort, and gives the impression that the fractured face showing the shells has been glazed over with a vitreous layer and polished. The outer contour is that of the cube carrying the usual well-defined square indentations. Unlike most hailstone forms, which cleave in the dodecahedral plane, the fractured face of this specimen lies in the octahedral plane. 0·5 carat.

Mr. J. Parry has kindly analysed two small diamonds carrying this cement crust. It was not possible to separate the diamond from the cement, consequently the specimens had to be treated entire. They gave only the familiar indication for iron, and a rather stronger one for magnesia. The actual proportions of these elements in the cement itself cannot, of course, be determined until a large enough sample can be procured separate. Meanwhile it seems reasonable to infer that the comparative softness of the cement is due to the magnesia, seeing that a considerable admixture of iron with diamond (*e. g.* stewartite) does not diminish the hardness at all.

Laminated Diamonds.

Laminated diamonds are very common. In one sense they appear to be examples of the general phenomena of overgrowths, and for that reason are included in this paper.

Suppose a model octahedron of glass to be split parallel to a pair of opposite faces into a number of thin laminae; next the laminae to be sealed

together in their original positions by means of a transparent cement slightly harder (or slightly less solvent) than the glass ; and lastly the edges of the octahedron to be abraded (or dissolved) away. The layers of cement being more resistant than the glass will stand out in slight relief as the attack proceeds.

Next let the same octahedron of glass be split again into thin laminae parallel to another pair of opposite faces and the cementing and abrading (or dissolving) process repeated. We shall obtain another set of layers protruding in relief and intersecting the first at a constant angle.

Finally, let the series of operations be repeated for laminae parallel to the two other pairs of opposite faces. The whole octahedron will now be spaced out into a device of small octahedra, marking its faces with a network of flush interlacing equilateral triangles, showing in relief on the reduced edges.

Laminated diamonds are exactly like this. The laminae are sometimes as thin as paper; more often they are in the vicinity of half a millimetre thick. They are not hemitropic. They alter the overall contour of a crystal very little, differing essentially in this respect from the macle, but on the other hand they modify the surface detail to some extent. The layers corresponding to the cement layers of the hypothetical glass model always protrude where they show themselves, and, as a rule, they may be easily felt with the finger-nail or with the edge of a knife. A formal analogy will be found in the octahedral structure of iron meteorites, wherein kamacite stands for the glass, and the less easily dissolved taenite for the cement.

The laminae scarcely ever manifest their existence save on the well-developed somewhat coarsely rilled faces of the rhombic dodecahedron or tetrahexahedron. On octahedron faces they are rarely seen, as also on the finely grained rounded edges of the octahedron (which are embryo dodecahedron and tetrahexahedron faces). On octahedron-dodecahedron combinations they may be traced all round a stone excepting where the octahedron faces interrupt. The intersections of the laminae with the octahedron faces, however, are often indicated by an array of indented triangles.

In the majority of cases only one set of parallel laminae appear on any one diamond. When two sets appear, intersecting on a solution face, one set is nearly always much more prominent than the other. An examination of a great number of laminated specimens has only determined a very few—and some of these doubtfnl—with more than two sets of laminae in one stone.

In Fig. 3 I have attempted to depict a laminated octahedron-dodecahedron combination from Wesselton, showing two sets of laminae. It is one of the rare cases in which the edges visibly cut the octahedron face. Though some relationship between the laminae and the indented triangles is shown, it is not so marked as in many other specimens, wherein, while

the edges themselves are not visible, their course is traced out by rows of little triangles, all much of a size, in a row.

On the rotating stage under the microscope the edges of the laminae give a singularly pleasing effect. They prove them to be more of the nature of steps down facing away from the shorter diagonals of the rhombic faces, than of definite protrusions; and their undeviating straightness, so different from the vacillating composition plane of the macle, contrasts sharply with the rippled surfaces they cut.

Geometrically, the shorter diagonal of a rhomb of a dodecahedron coincides with an edge of the derived tetrahexahedron. The same rule is approximately true for such diamonds as are of good symmetry, and are not

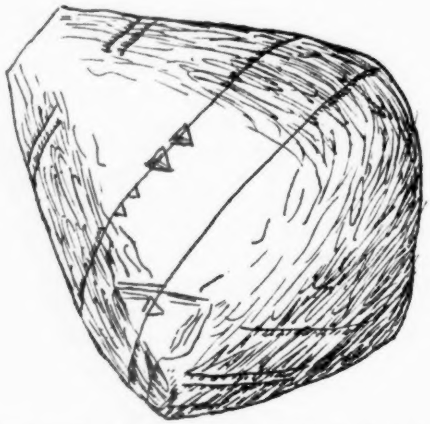

FIG. 3.—Laminated Wesselton diamond, enlarged.

laminated; but when diamonds are laminated the rule is varied, in that the tetrahexahedron edge tends to slant away from its geometrical position into parallelism with the edges of the laminae. This is, perhaps, the most important change made by the lamination on the aspect of a stone.

Fersmann and Goldschmidt have described ('Der Diamant,' 1911) three laminated diamonds, all Brazilian, namely: Crystal No. 26, an irregular lump of a weak violet colour, showing lamination in three directions; Crystal 32, a brownish regular dodecahedron, whose surface is covered by a delicate network formed of innumerable twin lamellae in four sets; and Crystal 33, a brown dodecahedron with coarse lamination. They argue that most diamonds may be presumed to be composed of such lamellae, and that the lamination is brought into view by the process of solution. They seem further to hold that hemitropic twinning is the cause of the phenomenon.

It is curious that their drawings of crystals 32 and 33 show the protuding edges of the lamellae as running nearly parallel with the edges of the rhombs, a feature not actually possible in nature. Indeed in this respect their version of the aspect of 33 differs absolutely from that of Rose and Sadebeck made some forty years earlier, and which they reproduce for comparison with their own.

Boutan also regards these laminated diamonds as macles by hemitrophy. He further regards Brewster's celebrated lens of diamond as having been cut from a multiple twin of this kind—a remote possibility, maybe, though not quite a probability, if only for the reason that a laminated stone is not likely to be transparent enough to serve as a good lens.

One reason against hemitrophy is that one sometimes comes across laminated stones which could just as well be called in the French way "macles by penetration," *i. e.*, tending to conform geometrically to the interpenetrating twins of the plus and minus tetrahedra; the lamination giving a terraced aspect to the blunt protruding pyramidal bosses very like the terraced diamonds from Jagersfontein in miniature. Another reason is that lamination is limited to four definite directions each of which is parallel to an octahedron face, so that in any laminated stone each multiple-twin set intersects another at a constant angle; and this is the case even when the specimen is a macle. But macles when they intersect one another are not limited to definite directions at all: their seams crossing almost at random much as irregularly twinned simple crystals interpenetrate.

Lamination has an intimate correlation with colour. With very few exceptions, all laminated diamonds, no matter where they come from, are coloured—brown, mauve, green, or blue-white. Slight lamination may also be seen once in a way on poor cape-white diamonds, and on poor yellow ones. Reflexively, nearly every brown, and nearly every mauve, dodecahedral diamond, either macle or simple crystal, whether the tint be light or dark, is plainly laminated.* So are most blue-whites when they are of a milky transparency or when their tint inclines to mauve. Lamination also occurs among the green diamonds from the Rand banket.

Hitherto I have only succeeded once in seeing signs of lamination in the interior of a diamond. This was in an ugly dark-brown brilliant in which the lamellae were marked out in alternating lighter and darker brown streaks. A fair inference seems to be that a diamond going in general through stages of growth and quiescence may, during the latter, become covered with colouring matter which is enclosed in a later growth. The apparent uniform tint of the final whole stone will be largely a refraction effect (like the grey

* The featureless brown diamonds of resinous lustre from South-West Africa do not show lamination so often as brown diamonds from other sources. For that matter South-West African diamonds seldom show any surface detail at all to speak of, saving either an exceedingly high polish or a roughening due perhaps to wind erosion.

colour imparted to coated stones by indefinitely thin layers of tiny black spots), and is the happier as the laminae are thinner. Thus the colouring matter is an overgrowth which establishes the lamination. There is no doubt that Heddle when he alleged the disseveration of "plate diamonds" ('Ency. Brit.,' 9th Ed., Art. "Mineralogy"), was confounding the mythical bursting of smoky stones with the lamination of brown ones.

[ADDENDUM.—While the above paper was going through the press I had the good fortune to see a most important specimen of diamond embedded in calcite, found by Mr. J. T. Vigne in the working over of some old Kimberley lumps. The diamond appears to be of about four carats, and the enclosing calcite perhaps five carats. The diamond has evidently not been squeezed into the calcite, but has acted as a nucleus upon which the latter has crystallised. Mr. J. Stewart has, also, given me a portion of a beautiful shell of calcite taken from a Wesselton blue-ground diamond. The interior faces of this shell have acquired, from their intimate contact with the diamond, an almost perfect adamantine lustre.]

SOME STATISTICS OF THUNDER AND LIGHTNING AT KIMBERLEY.

By J. R. Sutton.

The annexed Tables I, II, III, give summaries of the results of eye and ear observations of thunder and lightning made at Kimberley during the twenty-three years 1897 to 1919. They show, month by month, the duration of all the lightning seen, and of thunder heard, in the period. Division by twenty-three would give monthly means, but, in order to save decimal places, this has not been thought necessary. The numbers given in the tables must err in defect somewhat, since it cannot be that all lightning occurring has been seen, and all thunder heard, particularly during the hours between midnight and sunrise. The error, so far as thunderstorms are concerned, cannot amount to many hours, however, and certainly not by enough to displace the times of maximum and minimum.

Table I shows that thunder and lightning together, shortly thunderstorms, have a well-marked maximum a few hours before sunset in the warm months, and a few hours after sunset in the colder ones. The intermediate months show a tendency to a double maximum, one before and one after sunset. Moreover in July the diurnal variation tends to vanish altogether; while there is some evidence of a winter maximum some time between sunrise and noon.

The totals for the year show a maximum about 4 p.m. But this might be an illusory effect, seeing that the annual totals are made up for the most part of the large summer totals. For the purpose of eliminating the exaggerated effect of the summer numbers, the last column ("weighted year") has been computed. This column postulates an equal duration, *i. e.* 266 hours, of thunderstorm for each month, the hourly totals being reduced accordingly. The issue lessens the annual totals between noon and sunset, and enlarges the others, leaving the time of maximum unaltered. It also emphasises the influence of the winter maximum after sunrise.

Table II gives statistics of the duration of lightning without thunder seen during the same period. The numbers between midnight and sunset cannot claim much for themselves: first, because there was no systematic watch set between midnight and sunrise; and next because "sheet" lightning is not usually visible in daylight, only coming into view when the luminosity of the sky becomes less than that of the discharge.

Taking Table II as it stands, we have a maximum in each month about two hours after sunset. Now so-called sheet lightning is generally regarded as the reflection of distant thunderstorms. There is much to be said for the idea. On the other hand, since thunderstorms begin to decline in frequency before sunset, one would hence have expected, in view of the shortness of Kimberley twilight, the maximum to fall a little earlier than it appears to do. We should, indeed, anticipate a maximum as soon as the fading twilight glow would allow the lightning to be easily seen. And for more reason, that my sunshine charts are changed every day during civil twilight, and advantage is taken of the opportunity to search the horizon for lightning.

Another curious feature in the table is the greater relative rapidity with which the frequency of lightning runs down after about 8 p.m. as compared with the frequency of thunderstorms. Such a falling off depends in the main, no doubt, on the circumstance that Kimberley thunderstorms travel generally west to east.

Tables I and II are combined together in Table III. The total duration is 7130·5 hours; *i.e.* rather less than 1 hour in 29, on the average, has lightning or thunder or both together. In January the frequency rises to nearly 1 hour in 15.

At the foot of Table I is given the number of *nil* months, that is to say the number of months without thunderstorms in the period of twenty-three years. It may be gathered from this that a month without some sort of a thunderstorm is not to be expected in the summer half-year, October to March. The winter half had thirty-nine thunderstorms between them, practically every alternate July being free.

The next two lines in Table I show the greatest and least frequency in hours of thunderstorm weather in any one month of the period. March heads the list with 52·5 hours (in 1908), never falling below 7·3 hours (in 1902). No June, on the other hand, ever had more than 6 hours.

The next line shows the percentage of thunderstorm to the whole electric disturbance observed, as given in Table III. The great peculiarity here is the sudden rise in the thunderstorm ratio from May to June. It may be suggested as a fair inference either that the early winter thunderstorms overspread a greater area of country than the late autumn ones do; or (less likely) that they are local squalls which especially favour Kimberley. The local character of summer thunderstorms is well known. One of the most curious in my own recollection was a solitary large cloud, distant to the south-west of Kimberley, from three points of which rain, accompanied by lightning, was falling.*

The last line shows, in modern notation, the time of sunset for the

* *Cf.* an account in the 'Meteorological Magazine' for March, 1920, quoted from 'The Times,' of Central African thunderstorms observed from mid-air: "I have seen as many as a dozen of these storms [? at once] within an area of 100 square miles."

middle of each month. The first two digits stand for the hour, the second two for the minute. Thus, for January, "1854" means 18 hr. 54 min.—that is, 6.54 p.m.

The footlines in Table II are to be interpreted in the same way. The summer half shows one month (January, 1897) with no lightning observed. It is the first month of the observation period; and consequently there may be some reason to question the vigilance of the lookout. March again leads the list with a maximum duration amounting to 62·2 hours (in 1899) and a minimum of 7·5 hours (in 1915).

Kimberley thunderstorms are not confined characteristically to any state of barometric pressure, high or low. Statistics for five years give the following comparative numbers of these storms:

	Barometer high.	Barometer mean.	Barometer low.
January to March	55	24	50
April to June	5	3	20
July to September	8	8	19
October to December	43	23	47
Year	111	58	136

Hence in winter the few there are occur mostly with low pressures, whereas in the summer the barometric height is immaterial. What generally does happen in conjunction with the typical afternoon thunderstorm is a greater than normal fall of pressure from the morning maximum to the afternoon mimimum, as well as considerable and rapid variation while the storm is in progress.

Since the bulk of the rain on the South African Table-land falls in thunderstorms, Table IV is added for purposes of comparison. It gives the number of rainfall hours in the same observation period, 1897 to 1919. This is not to be interpreted as duration in the strict sense; but as the number of term hours in which rain was recorded, irrespective of whether it rained for each whole hour continuously, or only for a few minutes in each hour. Table IV agrees in its general features with Table I, albeit the turning points of its annual curve lag somewhat after those of the weighted annual curve of thunderstorms. There is a definite maximum of frequency about 4 p.m., and a definite minimum before noon. March has the highest frequency, August the lowest. The highest frequency in any one month goes to January, 1898, with 116 hours, for nearly 8½ in. of rain. During the whole observation period only one month (November, 1897) in the summer half had no rain at all, and only nineteen in the winter half had none. The statements one often sees in South African newspapers: "no rain for more than a year," "no rain for the last eighteen months," and so on, are untruths, although the cycle makers find them useful.

At the foot of Table IV will be found the total rainfall by months; from which we deduce the average fall per hour of rain given in the following line. Rain tends to fall heaviest in February. It falls lighter in October than in any other of the seven months September to March. This is of course due to the peculiarity of Kimberley rain—as yet unexplained—that a fall exceeding an inch a day in October is uncommon. The only heavy falls per twenty-four hours from 1897 to 1919 have been: In October, 1902, 1·05 in.; in October, 1906, 1·56 in.; in October, 1915, 1·14 in.; in October, 1918, 1·17 in.

There are records of heavier falls than these, in one day, in most of the other months.

The following table shows the monthly percentages of—

(1) day thunderstorms to night ones;
(2) day rain hours to night ones;
(3) day rainfall to night;

"day" being counted from 8 a.m. to 8 p.m., and "night" from 8 p.m. to 8 a.m.

	Thunderstorms (%).	Rain Hours (%).	Rainfall (%).
January	371	125	143
February	361	122	159
March	230	112	128
April	236	109	107
May	336	94	101
June	55	87	99
July	100	62	111
August	59	67	63
September	124	80	158
October	356	142	244
November	439	190	296
December	546	163	198
Year	306	117	152

We see from this that it rains more often by day in the summer at Kimberley, and more often by night in the winter. But the total fall in the winter is on the whole about the same night or day; so that with the exception of August the rate of fall is always greater during the day. At midwinter, also, thunderstorms favour the night hours.

On the average of the year, for every hour of night rain the fall is ·044 inch, and there is ·235 hour of thunderstorm; while for every hour of day rain the fall is ·057 inch, and ·616 hour of thunderstorm—not forgetting that the hour of rain is not the duration, whereas the hour of thunderstorm is.

Von Bezold and others have found that high temperatures produce years with abundant thunderstorms. The idea is not new; and it is in fact stated almost in so many words in the Anglo-Saxon Manual of Astronomy:— "Swa hattra sumor swa mara ȝunor ⁊ liget on geare." For that matter neither is it generally true. At any rate it is not true for Kimberley, where much rain, and therefore many thunderstorms, signify cooler weather. The following table gives the hourly mean temperatures of January arranged in order of magnitude, together with the total duration of thunderstorms, and of lightning without thunder, for the 20 years 1900 to 1919.

January	Mean Temperatures (Fahr.).	Thunderstorms (hours).	Lightning (hours).
1914	79·8°	15·0	29·0
1915	78·8°	19·2	47·5
1912	78·8°	20·5	27·2
1919	77·6°	17·2	26·0
1913	77·3°	35·5	37·0
1906	76·7°	7·2	15·0
1903	76·6°	21·5	28·0
1917	76·4°	29·5	10·5
1916	76·3°	37·7	37·0
1911	76·0°	4·5	20·5
1901	75·7°	20·7	33·2
1905	75·6°	46·5	29·2
1910	75·2°	21·2	39·5
1900	74·6°	16·2	12·2
1909	74·6°	18·0	22·5
1908	74·2°	28·2	18·0
1907	73·5°	33·0	52·7
1918	73·2°	18·7	36·0
1902	72·9°	21·0	23·2
1904	72·8°	13·2	23·7

From which we deduce for January mean temperatures above 75·9°:

Mean Thunderstorm duration . . .	20·8 hours.
,, Lightning ,, . . .	27·8 ,,
,, Total . . .	48·6 ,,

And for mean temperatures below 75·9°:—

Mean Thunderstorm duration . . .	23·7 hours
,, Lightning ,, . . .	29·0 ,,
,, Total . . .	52·7 ,,

The present essay was not intended to be more than statistical, compiled as a contribution to the meteorology of the Table-land of South Africa, and

TABLE I.—*Hourly Frequency of Thunderstorm at Kimberley.*

Hour ending	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Weighted year.
I . .	6·5	9·5	13·0	5·0	—	2·5	2·5	4·3	6·0	5·0	8·0	4·0	66·3	106
II . .	5·0	4·0	7·0	—	—	1·5	1·0	3·0	2·0	3·0	4·0	3·0	33·5	57
III . .	6·5	1·7	4·3	1·0	1·0	—	1·0	—	1·0	1·0	3·0	1·0	21·5	22
IV . .	4·5	—	3·0	3·0	1·0	1·0	2·0	—	2·0	—	2·2	1·0	19·7	35
V . .	1·5	1·0	6·0	2·0	—	—	3·0	—	1·0	0·5	—	—	15·0	27
VI . .	1·2	2·0	2·0	2·0	—	—	2·0	—	4·8	1·5	—	—	15·5	28
VII . .	2·0	3·5	4·2	2·0	—	1·0	1·0	1·0	3·3	3·5	2·3	0·2	24·0	38
VIII . .	—	4·0	3·3	4·0	—	1·0	—	2·2	1·2	4·0	3·5	1·8	25·0	40
IX . .	3·3	3·2	3·3	3·5	—	1·5	0·5	0·5	1·5	5·0	3·0	1·7	27·0	36
X . .	—	4·0	2·0	2·0	—	1·0	1·0	—	—	6·5	4·0	2·8	23·3	28
XI . .	0·2	2·5	1·3	3·2	3·0	1·0	1·0	—	1·0	6·0	7·0	1·5	27·7	42
Noon . .	3·3	6·5	5·7	1·5	2·5	1·0	3·0	—	1·5	6·2	14·3	10·5	56·0	67
XIII . .	19·0	15·3	14·5	5·7	1·2	1·0	2·0	—	3·2	8·3	33·7	21·3	125·2	103
XIV . .	45·5	31·5	34·5	13·0	6·0	—	2·5	—	7·0	18·2	36·8	46·3	241·3	193
XV . .	61·2	41·0	41·0	20·8	7·0	—	1·0	1·3	5·5	36·5	50·5	53·2	319·0	249
XVI . .	61·0	48·8	56·0	29·2	8·5	0·5	2·5	2·2	9·8	29·8	53·7	61·0	363·0	304
XVII . .	64·5	48·2	56·0	23·0	9·8	1·2	0·5	2·3	11·7	30·5	50·8	56·2	354·7	297
XVIII . .	68·5	48·8	47·7	22·5	7·7	1·0	3·0	2·0	9·5	32·8	49·0	49·0	341·5	290
XIX . .	52·0	42·0	50·7	23·8	4·5	2·5	3·0	3·7	8·8	29·7	28·8	45·3	294·8	271
XX . .	44·3	29·7	34·5	19·3	5·5	3·0	3·2	2·3	11·7	22·0	22·2	33·5	231·2	242
XXI . .	34·5	24·0	28·5	16·0	6·0	5·8	3·0	3·0	10·5	16·0	19·7	23·0	190·0	227
XXII . .	18·5	15·8	25·5	14·7	3·0	3·0	1·8	4·2	9·5	13·0	13·5	16·0	138·5	169
XXIII . .	22·5	11·7	27·5	13·0	3·0	4·0	2·5	2·5	8·0	10·0	14·8	14·0	133·5	160
Midnight . .	11·0	11·8	26·5	8·3	2·0	5·2	3·5	4·0	8·0	7·5	9·5	6·0	103·3	159
Total . .	536·5	410·5	498·0	238·5	71·7	38·7	46·5	38·5	128·5	296·5	434·3	452·3	3190·5	3190
Nil months .	0	0	0	3	6	9	11	8	2	0	0	0	39	
Maximum month	46·5	37·5	52·5	28·0	22·5	6·0	12·2	6·3	20·2	30·3	40·5	37·0	52·5	
Minimum month	4·5	2·7	7·3	—	—	—	8	—	—	0·2	1·0	7·0	—	
Percentage of disturbance .	46·2	41·2	44·0	35·7	34·2	51·8	56·2	44·3	50·9	48·8	51·5	44·6	44·7	
Middle time of sunset . .	1854	1837	1807	1730	1704	1658	1708	1726	1743	1801	1823	1847	1753	

TABLE II.—*Hourly Frequency of Lightning without Thunder at Kimberley.*

Hour ending	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
I	27·5	16·2	23·8	12·0	2·0	—	—	—	2·0	11·5	14·5	16·5	126·0
II	5·5	2·0	5·0	5·0	1·0	—	—	—	—	2·0	4·8	1·0	26·3
III	2·0	1·0	4·0	2·0	—	—	—	—	—	1·0	3·0	—	13·0
IV	1·0	—	2·0	—	—	—	—	—	—	—	—	—	3·0
V	1·0	—	—	—	—	—	—	—	0·3	—	—	—	1·3
VI	1·0	—	—	—	—	—	—	—	1·0	—	—	—	2·0
VII	—	—	—	—	—	—	—	—	—	—	—	—	—
VIII	—	—	—	—	—	—	—	—	—	—	—	—	—
IX	—	—	—	—	—	—	—	—	—	—	—	—	—
X	—	—	—	0·2	—	—	—	—	—	—	—	—	0·2
XI	—	—	—	—	—	—	—	—	—	—	—	—	—
Noon	—	—	—	—	—	—	—	—	—	—	—	—	—
XIII	—	0·5	0·5	—	—	—	—	—	—	—	—	1·5	2·5
XIV	1·0	—	—	—	—	—	—	—	—	—	—	1·5	2·5
XV	1·0	—	0·7	—	—	—	—	—	—	—	—	0·3	2·0
XVI	1·0	—	1·5	—	—	—	—	—	—	—	—	—	2·5
XVII	3·5	4·0	6·5	6·3	—	—	—	—	—	1·5	2·0	2·5	26·3
XVIII	5·0	7·0	14·5	19·5	11·5	1·8	—	2·2	5·0	6·5	5·2	9·0	87·2
XIX	31·8	34·0	77·5	77·5	23·5	3·0	4·5	11·0	24·5	50·7	55·3	30·7	424·0
XX	110·2	123·0	137·5	82·5	27·3	9·7	6·5	11·8	24·2	59·8	88·0	102·0	782·5
XXI	143·5	139·8	130·7	86·2	26·3	7·5	9·2	9·5	24·0	61·0	87·0	130·3	855·0
XXII	125·8	112·2	98·5	64·3	21·0	5·5	5·0	6·7	20·3	46·0	67·7	113·3	686·0
XXIII	92·0	84·2	74·3	47·2	12·5	5·0	6·0	4·3	13·2	38·0	46·8	93·5	517·0
Midnight	73·2	61·3	57·3	26·5	13·2	3·5	5·0	3·0	9·5	33·0	35·2	60·0	380·7
Total	626·0	585·2	634·3	429·2	138·3	36·0	36·2	48·5	124·0	311·0	409·5	561·8	3940·0
Nil months	1	0	0	3	4	13	14	10	4	0	0	0	49
Maximum month	52·8	54·2	62·2	46·8	21·2	9·0	10·5	13·3	15·2	37·5	33·8	45	62·2
Minimum month	—	0·3	7·5	—	—	—	—	—	—	1·5	3·2	2	—
Percentage of disturbance	53·8	58·8	56·0	64·3	65·8	48·2	43·8	55·7	49·1	51·2	48·5	55·4	55·3

TABLE III.—*Hourly Frequency of Thunderstorms and Lightning at Kimberley.*

Hour ending	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
I . .	34·0	25·7	36·8	17·0	2·0	2·5	2·5	4·3	8·0	16·5	22·5	20·5	192·3
II . .	10·5	6·0	12·0	5·0	1·0	1·5	1·0	3·0	2·0	5·0	8·8	4·0	59·8
III . .	8·5	2·7	8·3	3·0	1·0	—	1·0	—	1·0	2·0	6·0	1·0	34·5
IV . .	5·5	—	5·0	3·0	1·0	1·0	2·0	—	2·0	—	2·2	1·0	22·7
V . .	2·5	1·0	6·0	2·0	—	—	3·0	—	1·3	0·5	—	—	16·3
VI . .	2·2	2·0	2·0	2·0	—	—	2·0	—	5·8	1·5	—	—	17·5
VII . .	2·0	3·5	4·2	2·0	—	1·0	1·0	1·0	3·3	3·5	2·3	0·2	24·0
VIII . .	—	4·0	3·3	4·0	—	1·0	—	2·2	1·2	4·0	3·5	1·8	25·0
IX . .	3·3	3·2	3·3	3·5	—	1·5	0·5	0·5	1·5	5·0	3·0	1·7	27·0
X . .	—	4·0	2·0	2·2	—	1·0	1·0	—	—	6·5	4·0	2·8	23·5
XI . .	0·2	2·5	1·3	3·2	3·0	1·0	1·0	—	1·0	6·0	7·0	1·5	27·7
Noon . .	3·3	6·5	5·7	1·5	2·5	1·0	3·0	—	1·5	6·2	14·3	10·5	56·0
XIII . .	19·0	15·8	15·0	5·7	1·2	1·0	2·0	—	3·2	8·3	33·7	22·8	127·7
XIV . .	46·5	31·5	34·5	13·0	6·0	—	2·5	—	7·0	18·2	36·8	47·8	243·8
XV . .	62·2	41·0	41·7	20·8	7·0	—	1·0	1·3	5·5	36·5	50·5	53·5	321·0
XVI . .	62·0	48·8	57·5	29·2	8·5	0·5	2·5	2·2	9·8	29·8	53·7	61·0	365·5
XVII . .	68·0	52·2	62·5	29·3	9·8	1·2	0·5	2·3	11·7	32·0	52·8	58·7	381·0
XVIII . .	73·5	55·8	62·2	42·0	19·2	2·8	3·0	4·2	14·5	39·3	54·2	58·0	428·7
XIX . .	83·8	76·0	128·2	101·3	28·0	5·5	7·5	14·7	33·3	80·5	84·0	76·0	718·8
XX . .	154·5	152·7	172·0	101·8	32·8	12·7	9·7	14·0	36·0	81·8	110·2	135·5	1013·7
XXI . .	178·0	163·8	159·2	102·2	32·3	13·3	12·2	12·5	34·5	77·0	106·7	153·3	1045·0
XXII . .	144·3	128·0	124·0	79·0	24·0	8·5	6·8	11·0	29·8	59·0	81·2	129·0	824·5
XXIII . .	114·5	96·0	101·8	60·2	15·5	9·0	8·5	6·8	21·2	48·0	61·5	107·5	650·5
Midnight . .	84·2	73·0	83·8	34·8	15·2	8·7	8·5	7·0	17·5	40·5	44·7	66·0	484·0
Total . .	1162·5	995·7	1132·3	667·7	210·0	74·7	82·7	87·0	252·5	607·5	843·8	1014·0	7130·5

TABLE IV.—*Hourly Frequency of Rain at Kimberley.*

Hour ending	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
I	38	41	33	27	29	7	16	12	21	19	18	25	286
II	39	34	40	28	21	7	16	12	11	22	16	20	266
III	32	35	36	21	19	11	19	13	16	16	13	15	246
IV	19	26	43	29	21	9	16	12	16	17	12	17	237
V	30	32	43	30	17	8	18	10	9	16	9	17	239
VI	26	23	41	27	25	15	22	10	13	14	7	10	233
VII	19	24	39	25	23	12	14	9	10	13	10	15	213
VIII	22	29	38	26	23	9	10	10	9	14	10	18	218
IX	19	23	36	29	25	11	8	8	9	17	10	14	209
X	14	20	34	26	19	11	8	7	10	15	13	9	186
XI	15	23	34	27	22	6	8	6	9	14	16	9	189
Noon	14	27	35	16	20	8	9	4	8	17	17	11	186
XIII	28	30	36	27	20	8	10	7	7	18	31	24	246
XIV	50	45	50	33	18	7	12	4	13	23	37	45	337
XV	56	61	55	44	17	9	12	7	15	33	45	59	413
XVI	66	58	61	42	22	10	12	7	12	41	50	58	439
XVII	68	61	70	39	22	7	8	10	15	37	50	50	437
XVIII	59	64	63	33	19	10	13	10	18	39	43	58	429
XIX	62	65	66	31	20	14	12	9	17	33	38	57	424
XX	56	51	71	39	15	10	12	7	19	37	36	53	406
XXI	56	58	63	36	18	12	19	8	24	26	36	49	405
XXII	46	50	66	32	21	12	14	8	19	23	28	31	350
XXIII	44	49	59	40	15	13	20	11	20	22	23	29	345
Midnight	35	33	44	33	23	12	16	13	22	26	21	28	306
Total	913	962	1156	740	494	238	324	214	342	552	589	721	7245
Nil months	0	0	0	1	1	4	4	5	4	0	1	0	20 hours
Maximum month	116	81	87	95	59	26	52	62	58	48	58	72	116 ,,
Minimum month	16	10	9	—	—	—	—	—	—	2	—	4	— ,,
Total rain	54·52	61·05	68·11	30·61	17·08	6·25	9·10	4·80	18·27	26·89	32·47	39·95	369·10 inches
Average fall per rain hour	·060	·063	·059	·041	·035	·026	·028	·022	·053	·049	·055	·055	·051 inch

possibly of some use to airmen. Yet it may be of interest to note that Clement Ley claimed ('Met. Mag.,' 1876) that the thunderstorms of Western Europe are divisible into three distinct classes. Abercromby claimed (B.A. 'Report,' 1887) that there are at least three. Sir Napier Shaw remarks ('Forecasting Weather,' 1911, p. 293) that "the conditions under which thunderstorms should be forecasted are as various as the types of thunderstorms themselves." Clement Ley put it in this way:

"Those of the first class predominate in the winter months. They are far the most numerous on the western shores of Europe. They occur with low, or very low, barometrical pressure, and most commonly with steep gradients and strong winds, and are almost confined to the southern segments of depressions. They rarely take place when there is any very great difference between the direction of the upper and under currents. They are equally common by night and by day. The altitude of the storm clouds in this class is seldom so great as in the other two classes. Hail or snow frequently accompanies them. They are eminently local, and may, I think, be conveniently distinguished as *thunder-squalls.*

"Storms of the second type are very rare, except in the warmer months. They are least common upon our western coasts. They predominate with light winds, with moderately low pressure, and in the southern segments of depressions, but they are not at all particular as to the amount, or as to the distribution of pressure. They are local in character, but may be very severe. They occur almost exclusively by day. Their formation may often be readily watched; cumulus, frequently under a sky devoid of upper cloud, swells ot cumulonus; the summit of the latter assumes the cirri-form aspect, and a massive local nimbus is developed. I would denominate them *thunder-showers.*

"The third class are *thunderstorms, par excellence.* They belong to the warm season. They are remarkably rare on our extreme western coasts. . . . They are most common . . . when the isobars show local irregularities. But their most distinctive characteristic is the presence of an extensive and generally rapid southerly upper current (with more or less antagonistic surface winds) carrying cumulo-stratus over a wide area, especially to the northward and eastward of the storms. Storms of this class are as common by night as by day. They are usually less local than the others. They travel at a great altitude, are often exceedingly intense, and afford the grandest electrical display, but are productive of remarkably few accidents in proportion to the number of discharges. Their first development can rarely be watched to advantage; but the process appears to be the reverse of that which occurs in the 'thunder-showers,' the aggregation commencing in the higher regions of the atmosphere, and being propagated downwards."

Comparing this account with my statistics, it would seem that Kimberley

winter thunderstorms conform in some respects to Ley's first class; those of the other seasons more to that of his second class. Both divisions of the year, however, have storms which have points of resemblance to his third class. But these are details which I hope to discuss at some more favourable time.

A phenomenon of interest is the "smell" of a thunderstorm. This I have only observed once in Kimberley, and that strongly. European meteorological literature of the seventeenth and eighteenth centuries has many allusions to the "sulphureous smell" of lightning, especially when anything was struck; and the observation goes back even to the time of Homer (*Odyssey*, XII). Before the time of Franklin theorists had, because of this odour, attributed lightning to the "breath of pyrites."

SOUTH AFRICAN PERISPORIACEAE.

By Ethel M. Doidge.

(With seven Text-figures).

(Read May 19, 1920.)

VI. The Haustoria of the Genera Meliola and Irene.

The genus *Meliola* has received considerable attention from systematists, and is much studied from the taxonomic point of view by collectors and students of tropical and sub-tropical fungi. Comparatively little, however, is known of their method of nutrition or of their relation to the forest trees and shrubs, on whose leaves and shoots they are chiefly found. This is possibly due to the fact that until recent years these fungi were for the most part described by workers in Europe, who only had at their disposal scanty material sent to them by collectors in the Tropics.

The earlier workers, such as Bornet (1) and Gaillard (2), stated that the lesions which one sometimes observes on leaves on which these fungi grow are due to the action of numerous mites, of which one often finds the remains. Gaillard even states that he has satisfied himself by examining numerous sections that the vegetation of the *Meliolas* is entirely superficial, and does not in any way attack the tissues of the plant on which it grows.

In 1908 these statements were challenged by Maire (3) on observations which he had made on four fungi of the genus *Meliola*. The view held by some of the earlier workers that the *Meliolas* are entirely superficial and grow like the Capnodiums on the honey-dew produced by insects, he rejects on the grounds that close observation has shown that the development of these fungi is quite independent of the presence of any insects.

A second hypothesis is that the fungus derives its nourishment by osmotic interchanges between their hyphae applied to the cuticle and the epidermal cells. Maire observes that this is improbable, since the hyphae are separated from the cavity of the epidermal cells by a layer of impermeable cutin, of which the thickness is often several times that of the hypha. Moreover, the effect of the *Meliolas* on their host—neglected by most authors—is quite evident in certain cases; for instance, extended purple spots are found on leaves of *Schinus*, radiating from the point covered by the *Meliola* mycelium, and no other cause can be found for the discoloration.

Maire based his observation on four species: *Meliola amphitricha* Fr. on *Schinus molle*, *M. Negeriana* on *Lomatia obliqua*, *M. brasiliensis* var. *sanguineo-maculans* on *Schinus* sp., and one of the two European species, *M. nidulans* on *Vaccinium myrtillus*.

On examining numerous sections he found small haustoria in certain epidermal cells; these appear in the form of a very fine tube with brown walls and very clear lumen, which traverses the cuticle perpendicular to its surface or somewhat obliquely. When the cuticle is not very thick the tube traverses it without any sensible modification, and expands in the cavity of the cell into a more or less spherical vesicle with a thin hyaline wall—*e. g.* in *Schinus* sp. attacked by *Meliola brasiliensis* var. *sanguineo-maculans* and *M. amphitricha*.

When, on the contrary, the cuticle is thick, the tube completely changes its form and contracts into an extremely fine, filiform tract (about $\frac{1}{2}\,\mu$ diam.), staining bright blue with lactophenol and cotton blue, in which it is impossible to observe the protoplasmic membrane. This filiform tract expands in the cell cavity in a similar way to the one described above.

Maire experienced some difficulty in finding sections showing the actual connection of the haustoria with the hypha, as the latter frequently fall away in sectioning; but after examining a large number of sections, haustoria were found adhering to the hyphae from which they were produced. He concludes from this evidence that the *Meliolas* are true parasites, deriving their food supply from the epidermal cells of the host by means of haustoria.*

The genera *Meliola* and *Irene* are well represented in many parts of South Africa, and over fifty species have been recorded (4), although there are still many promising localities in which no collections have been made. In view of the prevalence of these fungi on our forest trees, it was suggested to me by Dr. J. W. Bews that they might have an important bearing on plant succession in the forest belts. Seedling trees are especially subject to the attacks of fungi belonging to the genus *Meliola*, and it is not uncommon to find the leaves of seedlings of certain susceptible species so covered with dark mycelium that the normal green colour is only to be seen where young leaves have recently unfolded. It therefore was a matter of considerable interest to discover to what extent the *Meliolas* are parasitic and to confirm and extend the observations made by Maire.

Dried material from the National Herbarium was employed, and although recent collections were chosen where possible, satisfactory preparations were obtained even from old material. Small areas covered with the mycelium of the fungus were cut out and boiled in 10 per cent. formalin

* A number of valuable papers by G. Arnaud, containing references to the haustoria of the *Microthyriaceae* and allied families, only came to my notice when this paper was in the press, and have not been taken into consideration.

until most of the air was expelled from the tissues, and the portions of leaf sank to the bottom of the tube. When the formalin was cold, sections were cut with the freezing microtome and transferred direct from the 10 per cent. formalin to the stain.

The stain employed was Guéguen's triple stain (5), which was recommended by Maire as giving beautiful preparations. This is a solution of Sudan III and "bleu coton" (Bleu C_4B Poirrier) in lactic acid, but "bleu coton" not being obtainable methyl blue was used and proved to be a very satisfactory substitute. The sections were left in the stain for fifteen to thirty minutes, and were then mounted and examined in lactic acid. Successful preparations showed the cuticle stained a beautiful clear red, while the haustoria and the contents of the external fungus hyphae were stained bright blue.

Some of the species of *Meliola* are very readily detached from the host, and a considerable search had to be made before sections were found showing the haustoria attached to the hyphae from which they were derived; others adhere more closely and no difficulty was experienced in demonstrating the attachment of the haustoria.

A fairly large number of species was examined, and these will be considered separately.

Meliola amphitricha Fr. has been recorded from this country on a number of hosts chiefly belonging to the Rubiaceae. The first specimen examined was on *Sapindus oblongifolius*. This plant has an ordinary mesophytic type of leaf with a fairly thick cuticle on the upper side, the cells of the lower epidermis are smaller than those of the upper, and the cuticle on the under surface is much thinner. Haustoria were present in great numbers in the epidermal cells, and the fungus being amphigenous they were observed on both the upper and the lower surface. In every case they consisted of a very fine filiform tract—which may be termed the penetrating filament—traversing the cuticle and expanding just within the epidermal cell into a small spherical thin-walled vesicle. The whole haustorium stains bright blue by the method used, and the vesicle has a single central nucleus which stains more deeply. This type of haustorium is very similar to that described by Harper (6) for many of the Erysiphaceae. On *Grumilea caffra*, which has a very thin cuticle, *Meliola amphitricha* has exactly the same type of haustorium as on *Sapindus oblongifolius*; a fungus on *Jasminum streptopus*, which is placed under *M. amphitricha*, was also examined and found to have the same type of haustorium.

The leaf of *Olea laurifolia* has a thick cuticle on the upper surface and edges, the distance from the leaf surface to the lumen of the epidermal cells being 12 to 13 μ; on the lower surface the cuticle is thinner, the distance being only 4·5 to 5 μ. There are sclerenchyma fibres scattered through the mesophyll, and occasionally occurring between the epidermis and the

palisade cells. A *Meliola* species on this host closely resembles *M. amphitricha*, and was assigned to this species, as I was in doubt as to whether the morphological differences justified describing it as distinct from *M. amphitricha*. This fungus occurs on both sides of the leaf.

No difficulty was experienced in demonstrating the haustoria of this fungus, and in observing their connection with the hyphae on the leaf surface. The penetrating filament is ·6–·75 μ thick, and stains bright blue. It passes through the cuticle, but instead of expanding into a spherical vesicle in the epidermal cell, it traverses the epidermis and penetrates into a palisade cell, or the first cell of the mesophyll encountered, according to whether the fungus is growing on the upper or under surface of the leaf. If a sclerenchyma fibre is encountered it pierces through it and so reaches a chlorophyll-bearing cell, where it expands into a thin-walled, spherical, uninucleate vesicle. The fungus, therefore, is obviously a distinct species from *M. amphitricha*. It was suggested that the character of the leaf might in some way be responsible for the form of the haustoria. Two other species of *Meliola* occur on *Olea laurifolia*, and these were examined in order to discover whether they produced the same form of haustorium.

Meliola petiolaris Doidge occurs chiefly on the petioles and on the under sides of the leaves, but often spreads somewhat from the lower side over the upper margin. On the lower surface the fungus has haustoria similar to those of *M. amphitricha*, consisting of a fine filament penetrating the cuticle and a small, spherical vesicle, about 3 μ diam., in the epidermal cell. Near the edge on the upper surface, where the cuticle is much thicker, the haustoria are similar in character, but the penetrating filament is stouter and brown-walled. This change in the character of the penetrating filament appears to be correlated with the thickness of the cuticle, and is very unusual; in every other case the form of the haustorium has been found constant for any given species. Of all the specimens examined this was the only species, with a vesicle in the epidermal cell, in which the penetrating filament retained the brown colouring of the wall of the parent hypha. Maire mentions two species, *Meliola brasiliensis* var. *sanguineo maculans*, and *M. amphitricha* on *Schinus* sp., which have this peculiarity, and considers that in hosts with a thin cuticle the tube traverses the cuticle unchanged, but when the cuticle is thick the tube decomes a very fine, filiform tract with hyaline walls. In the majority of cases I have found that there is no relation between the thickness of the cuticle and the nature of the wall of the penetrating filament, which appears to be a specific character. In the case of *M. petiolaris* the tendency is for the filament to be brown-walled and stouter where it penetrates the *thicker* cuticle.

It will be noticed that Maire found a brown penetrating filament in leaves of *Schinus* attacked by *M. amphitricha*, whereas on other hosts in South Africa this fungus has a fine, hyaline penetrating filament, which stains blue with

Gueguen's triple stain. I think it is probable that the species *M. amphitricha* as at present constituted consists of a number of species which are morphologically similar, and that the form of the haustoria should be taken into consideration by taxonomists.

The third species parasitic on *Olea laurifolia* is *Irene ditricha* (K. & Cke.), Doidge, which occurs on the upper surface. The penetrating filament is thin walled, staining blue; it traverses the cuticle and the epidermal cell and expands into a globular vesicle just inside one of the palisade cells. It thus differs from the first of the fungi described on this host only in the broader penetrating filament, which in this case is about 1·5 μ thick.

Irene ditricha also occurs on *Celastrus* sp.; the form on *Olea laurifolia* differs in one or two minor points, and should perhaps be considered a variety. The leaf of this plant becomes discoloured over a considerable area, the centre of which is the *Meliola* mycelium; the discoloured parts become yellowish brown. This fact makes the leaf rather an unfavourable one for study as the contents of the epidermal and hypodermal cells are badly disorganised and stain deep blue. The haustoria appear to be similar to those of *I. ditricha* on *Olea laurifolia*.

Meliola carissae Doidge occurs on *Carissa arduina*, which has a leaf with a very thick cuticle. The penetrating filament is fine, staining blue, but its walls are often brown or brownish for a short distance where it enters the cuticle. The vesicle is in the epidermal cell, and is of the usual type, thin-walled, globular, hyaline and uninucleate.

Meliola leptidea Syd. on *Cussonia umbellifera* has also what may be termed the ordinary type of haustoria, with a fine penetrating filament and a globular vesicle in the epidermal cell. These are very small and inconspicuous, but the contents of the epidermal cells are obviously disorganised and filled with a granular deposit.

This type of haustorium was also produced by *Meliola ganglifera* K. & Cke. on *Curtisea faginea* and *M. capensis* (K. & Cke.) Th. on *Hippobromus alatus*.

Meliola bifida Cke. on *Osyridicarpus natalensis* occurs on the stems, and no satisfactory preparations could be obtained of this species, as the stem was too hard to cut with the freezing microtome, and the fungus very readily became detached from the host.

Meliola Evansii Doidge is found on *Scolopia* sp. Here the haustorium penetrates to the hypodermal cell (Fig. 1). The penetrating filament is hyaline and stains blue, but is fairly stout, and the expanded vesicle is formed in the chlorophyll-containing cell of the mesophyll which is encountered.

Exceptionally clear preparations were obtained of *Meliola arcuata* Doidge on *Viscum anceps* (Fig. 2). The stem—it is a leafless species of *Viscum*—has a very thick cuticle which is traversed by a fine penetrating filament, and swells into a globular uninucleate vesicle just inside the epidermal cell.

Irene natalensis Doidge is found on several species of *Doryalis*. The specimen selected was on the upper surface of the leaves of *D. tristis*, which have a thin cuticle. The penetrating filament has brown walls like those of

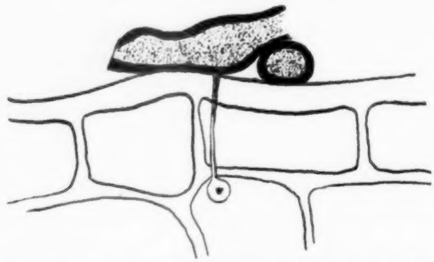

FIG. 1.—Haustorium of *Meliola Evansii* penetrating into leaf of *Scolopia*, sp. (comp. oc. No. 8). All the figures were drawn with the aid of the camera lucida and a Zeiss $\frac{1}{12}$-in. oil-imm. obj.

the mycelial hyphae, but very much thinner, and it passes through the epidermis into the first layer of palisade cells, the expanded vesicle being just within the latter. These haustoria differ from those of *M. Evansii* in

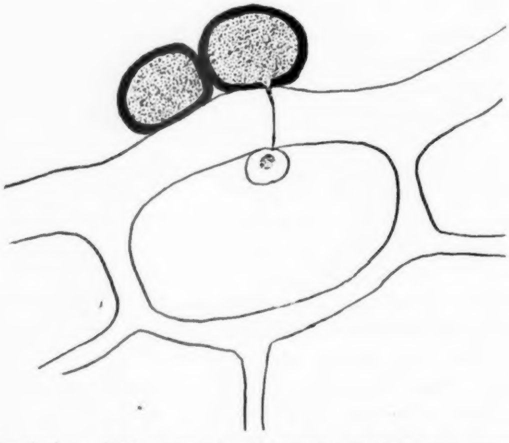

FIG. 2.—Haustorium of *M. arcuata* in epidermal cell of *Viscum anceps* (comp. oc. No. 4).

the brown coloration of the walls of the penetrating filament. The latter may be at right angles to the leaf surface, but is very often oblique and sometimes its course is quite crooked or even tortuous.

Irene puiggarii Speg., which occurs on a number of rosaceous hosts, is

morphologically similar to *I. natalensis*, differing only in minor points in the form of the hyphopodia and spores. It is interesting to find, therefore, that the haustoria are of a different type. Those of *I. puiggarii* have a fine, blue-staining penetrating filament, and a small uninucleate vesicle about 6 μ diam. in the epidermal cell. The specimen examined was on *Cliffortia strobilifera*, which has not a very thick cuticle, but it is wavy in outline. The difference in the haustoria cannot be accounted for by the character of the host plant, for both species occur on plants with quite a mesophytic type of leaf.

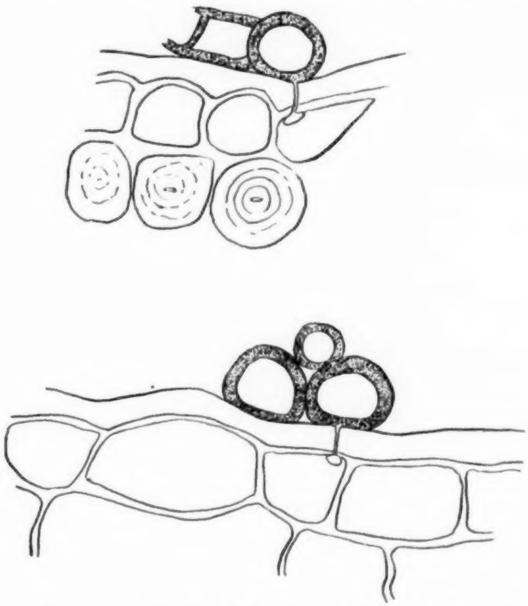

FIG. 3.—*M. Podocarpi* on leaf of *Podocarpus falcata* (comp. oc. No. 8).

Some of the most interesting results were obtained in connection with two fungi parasitic on *Podocarpus* spp., which further emphasise the fact that the form of the haustorium is a specific character, and is not dependent to any great extent on the structure of the host.

Irene podocarpi Doidge is found on *Podocarpus Thunbergii*, *P. falcata* and *P. elongata*, and specimens on the two last-named hosts were examined. This fungus has the most usual form of haustorium, consisting of a thin-walled penetrating filament with a small vesicle in the epidermal cell (Fig. 3). It occurs mostly on the under side of the leaf where the cuticle is not very thick.

Meliola peltata Doidge occurs on *P. Thunbergii* and *P. falcata*; these two species have a very similar leaf structure, while that of *P. elongata* differs considerably, being quite of the ordinary mesophytic type.

The leaves of the first two species have a thick cuticle, especially on the upper side, and just under the epidermis there are one, two or three rows of sclerenchyma fibres. These form a continuous band on the upper surface, but on the lower surface they are interrupted in the neighbourhood of the stomata.

The fungus examined was on the lower surface of *P. Thunbergii*; it closely follows the contour of the leaf, completely blocking the depression above the stomata and pressing on to the guard-cells. This circumstance, which has not been mentioned before, was noticed in a number of the species examined and is apparently of constant occurrence (Fig. 4).

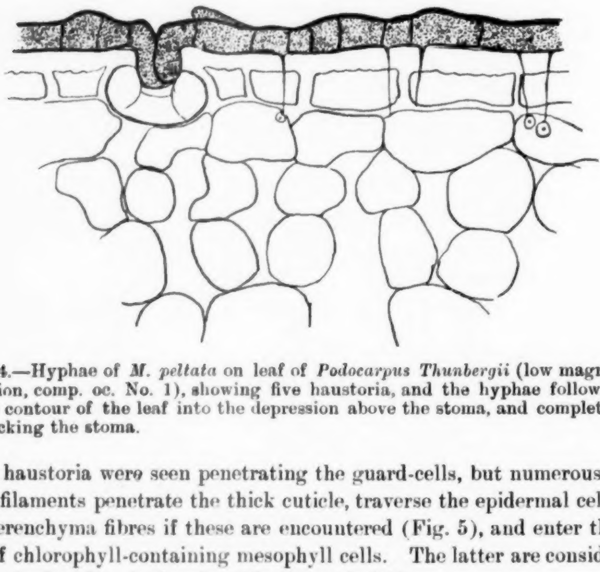

FIG. 4.—Hyphae of *M. peltata* on leaf of *Podocarpus Thunbergii* (low magnification, comp. oc. No. 1), showing five haustoria, and the hyphae following the contour of the leaf into the depression above the stoma, and completely blocking the stoma.

No haustoria were seen penetrating the guard-cells, but numerous thick-walled filaments penetrate the thick cuticle, traverse the epidermal cells, and the sclerenchyma fibres if these are encountered (Fig. 5), and enter the first layer of chlorophyll-containing mesophyll cells. The latter are considerably disorganised and stain deeply with the methyl blue.

Where it begins to penetrate the cuticle the haustorium is slightly bulbous or funnel-shaped, and measures 4·6–5 μ in diameter (Fig. 6). This diameter immediately below decreases to about 1·5 μ, often continuing to taper slightly till it reaches the mesophyll cell, where it expands into a globular or ovoid vesicle, 4·5–5 μ diam. The penetrating filament is brown throughout, but becomes paler as it grows away from the external hypha; the vesicle is delicate, hyaline, stains a clear blue, and has a single, central,

deeply staining nucleus. The shortest penetrating filaments, found where the chlorophyll-containing cells were immediately under the epidermis, were 17–20 μ long; the average length where two sclerenchyma fibres were traversed was 40 μ (Fig. 6), and in exceptional cases where there were three layers of fibres under the epidermis they were up to 60 μ long. Cases were observed where the haustorium pierced through the lateral wall of the epidermal cell (Fig. 7).

The haustoria could be readily picked out with the low power of the microscope; fairly thick sections were better than extremely thin ones, as the latter did not show the entire course of the penetrating filament. The filaments were for the most part straight and perpendicular to the leaf surface or somewhat oblique, but a few were curved or even tortuous.

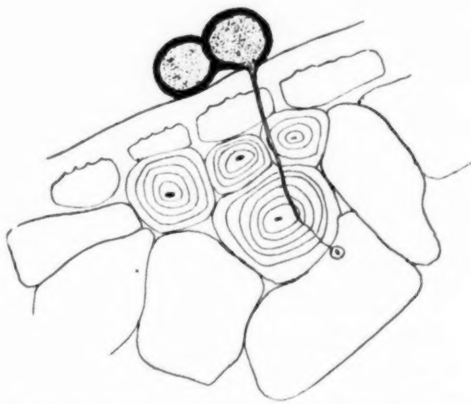

Fig. 5.—Shows the haustorium of *M. peltata* penetrating through two sclerenchyma fibres (comp. oc. No. 2).

The penetrating power of the haustorium is best realised in examining a transverse section, in which the thickness of the walls of the sclerenchyma fibres is most evident (Fig. 5). On the upper surface of the leaf on which the fungus is able to flourish, the distance from the leaf surface to the first chlorophyll-containing cells is often as much as 130 μ.

The other genera of the *Perisporiaceae* are poorly represented in South African species in the National Herbarium. Two of these fungi, *Zukalia transvaalensis* and *Phaeodimeriella capensis*, on careful study proved to be parasitic on *Asterina* spp., the hyphopodiate mycelium described for these two species being that of the host, and the mycelium actually belonging to them forming a weft of pale fine hyphae investing the *Asterina* mycelium. *Zukalia transvaalensis* should therefore be placed in the genus *Perisporium*.

Dimeriella annulata Syd. has a large part of its mycelium internal to the leaf, lying between the cuticle and the epidermis, and therefore does not belong to the genus *Dimeriella* as at present defined.

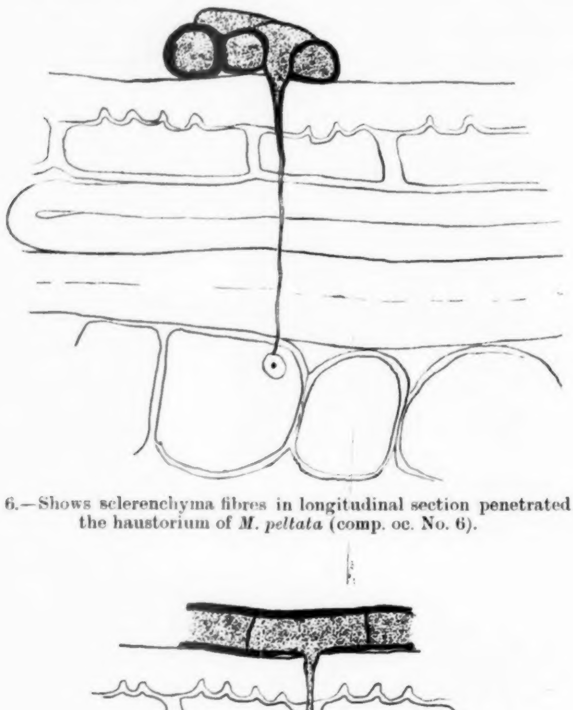

FIG. 6.—Shows sclerenchyma fibres in longitudinal section penetrated by the haustorium of *M. peltata* (comp. oc. No. 6).

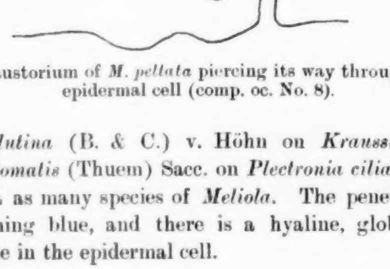

FIG. 7.—Haustorium of *M. peltata* piercing its way through in wall of epidermal cell (comp. oc. No. 8).

Balladyna velutina (B. & C.) v. Höhn on *Kraussia floribunda* and *Dimerium psilostomatis* (Thuem) Sacc. on *Plectronia ciliata* have the same type of haustoria as many species of *Meliola*. The penetrating filament is thin-walled, staining blue, and there is a hyaline, globular, thin-walled uninucleate vesicle in the epidermal cell.

SUMMARY.

The fungi belonging to the genus *Meliola* are true parasites, sending haustoria into the cells of the host.

The most common type is that which has a fine filament penetrating the cuticle and a small, globular, thin-walled, uninucleate vesicle in the epidermal cell.

The nature of the filament, whether hyaline or brown, thick or thin, appears to be a character specific to the fungus concerned, and is not generally, as suggested by Maire, correlated with the thickness of the cuticle to be traversed.

Certain species penetrate through the epidermis, through sclerenchyma cells, if these are present, into the first chlorophyll-containing cells of the mesophyll; but the form of all the haustoria examined was in general the same, consisting of a penetrating filament and a delicate uninucleate vesicle. The differences in different species consist in the length and character of the penetrating filament.

The character of the penetrating filament is of diagnostic value; and may, in some cases, be employed as a determining factor when there is any question of the identity of two species.

The haustoria cause a considerable disorganisation of the cells into which they penetrate, and the mycelium completely blocks many of the stomata. The fungi of the genus *Meliola* must therefore have a prejudicial effect on plants which are heavily infected, especially on the young seedling trees which seem to be generally susceptible.

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COLOUR AND CHEMICAL CONSTITUTION.

PART XI.—A SYSTEMATIC STUDY OF THE BROMINATED PHENOLPHTHALEINS REGARDING THE RELATION BETWEEN POSITION AND COLOUR.

BY JAMES MOIR.

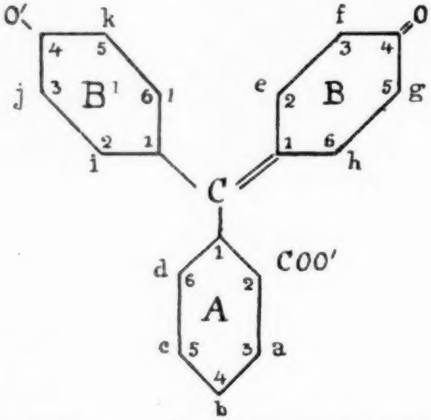
In Part IX of this work a mathematical formula was developed whereby the colour of any halogenated phenolphthalein could be calculated. The application of this formula was, however, in practice limited to substances halogenated in the phenol rings, it being known that the four phthalic positions are very abnormal (although the four taken together are very nearly equivalent to four phenolic positions).

The formula when confined to the halogen bromine alone reads $\frac{\lambda_0}{\lambda} = 1 - 0{\cdot}0128m$, or since in phenolphthalein $\lambda_0 = 554$, $\lambda = \frac{554}{1-0{\cdot}0128m}$, in which m is the number of (ortho) bromine atoms present in the brominated phenolphthalein the colour of which is to be calculated. For meta-bromine atoms m is to be doubled. The expression $\frac{554}{1-0{\cdot}0128m}$ can for simplicity be written without a divisor as $554\ (1 + 0{\cdot}0128m + 0{\cdot}000164m^2)$, hence finally $\lambda = 554 + 7{\cdot}091m + 0{\cdot}091m^2$. Terms containing higher powers of m are negligible.

Hence if m is a small number, less than 5, the wave-length may be taken to be $7\frac{1}{2}$ units higher than 554 for each ortho-bromine atom present. Thus $561\frac{1}{2}$, 569, $576\frac{1}{2}$ and 584 are the wave-lengths of (ortho) mono-, di-, tri- and tetra-bromophenolphthalein. This, though not strictly accurate, agrees with observation within one unit.

I have, however, shown in Part II (foot of p. 113) that substitution of a second phenolic ring produces less effect than substitution of the first ring, the latter producing about 58 per cent (or four-sevenths) of the effect of substituting both phenolic rings, and the former 42 per cent. (or three-sevenths) of the effect.

I have now completed the study of the effect of bromine on colour by preparing the phthaleins derived from the brominated phthalic acids, and am now able to give a tabular statement showing how the position of the bromine atoms affects the colour, and enabling that of any polybromo-derivative to be calculated, since the property is additive.



Systematic nomenclature of the positions in alkaline phenolphthalein.

Table giving Value in Colour-change of a Bromine-atom in the Different Substituting Positions.

Position	*b*	or A4	has	value	1
"	*j*	" B′3	"		7
"	*k*	" B′5	"		7
"	*c*	" A5	"		8
"	*f*	" B3	"		8
"	*g*	" B5	"		8
"	*a*	" A3	"		10
"	*d*	" A6	"		10
"	*i*	" B′2	"		13
"	*l*	" B′6	"		13
"	*e*	" B2	"		15
"	*h*	" B6	"		15

NOTE.—These values are to be added to 554 to get the wave-length of the absorption of the brominated phenolphthalein.

The unit is 1 in the third place of wave-lengths = 10 Angstrom units.
The positions are not in alphabetical order, but in order of magnitude.

It is to be noted, however, that the difference between the positions *f*, *g*, *j* and *k* does not come into play unless there is substitution in *both* rings B and B′: thus there is only one mono-orthobromphenolphthalein, which I

assume to be the *f* or *g* derivative, not the *j* or *k* derivative: the same holds of the positions *e*, *h*, *i* and *l*, there being only one mono-metabromphenolphthalein. On inspection of the figure it will be seen that only five distinct monobromphenolphthaleins are to be expected, or at all events, although six are possible (*a*, *b*, *c*, *d*, *e* and *f*), yet the *a* and the *d* derivatives either have the same spectrum or are never formed together when 3-bromophthalic acid is condensed with phenol (this might be expected owing to "protection," which would prevent the formation of the *d* derivative).

Monobromophenolphthaleins.

Position of bromine atom.	Method of formation.	Observed band-centre.	Calculated from position-law.
a	3-bromophthalic acid and phenol	λ 566	λ 564
b	Bye-product of *c*	λ 556*	λ 555
c	4-bromophthalic acid and phenol	λ 561*	λ 562
e	OBBA† and monometabromphenol	λ 567	λ 569
f	OBBA† and mono-orthobromphenol	λ 561½	λ 562

* Imperfectly separated. † OBBA = 4-oxybenzoylbenzoic acid.

For comparison with the first of these, *a*-monochlorphenolphthalein was made. Its band-centre was at λ 563.

As regards the dibromophenolphthaleins, there appear to be 21 possible isomers, viz.: (1) *a–d* from 3-6-dibromphthalic acid; (2) *b–c* from 4-5-dibromphthalic acid; (3) *a–b* and (4) *c–d* from 3-4-dibromphthalic acid; (5) *a–c* and (6) *b–d* from 3-5-dibromphthalic acid; (7) *a–e* and (8) *d–e* from 3-(6)-bromo-4′-oxybenzophenone-2-carboxylic acid and metabromphenol; (9) *b–e* and (10) *c–e* from the isomeric 4-(5)-bromo acid; (11) *a–f* and (12) *d–f* from the former acid and orthobromphenol; (13) *b–f* and (14) *c–f* from the isomeric 4-bromo-4′-oxybenzophenone-2-carboxylic acid and orthobromphenol; (15) *e–f* from OBBA† and 2-3-dibromphenol; (16) *e–g* similarly from 2-5-dibromphenol; (17) *e–h* similarly from 3-5-dibromphenol; (18) *f–g* similarly from 2-6-dibromphenol; (19) *e–i* from phthalic acid and 2 mols. metabromphenol; (20) *f–j* from phthalic acid and 2 mols. orthobromphenol; and finally (21) *e–j* by condensing phthalic acid first with orthobromphenol and then with metabromphenol.

Of these 21 isomers, 4 may be eliminated if we assume that the colour-effect of the *d*-position is the same as that of the *a*-position; these 4 are *b–d*, *c–d*, *d–e* and *d–f*. Of the 17 remaining I have, of course, only been able to prepare and examine a very few, owing to lack of starting-substances in South Africa, and the following table exhibits the results obtained:

Dibromophenolphthaleins.

Position of bromine atoms.	Method of formation.	Observed band-centre.	Calculated from position-law.
a–d	3-6-dibromphthalic acid *ex* 1-4-dibromnaphthalene	λ 573	λ 574
b–c (?)	4-5 (?) dibromphthalic acid *ex* silver phthalate + $2Br_2$	λ 564	λ 563
a–c	3-5 dibromphthalic acid *ex* anthranilic acid	λ 571	λ 572
f–g	OBBA and 2-6-dibromphenol	λ 570	λ 570
f–j	Phthalic acid and 2-bromophenol	λ 569	λ 569

The number of tribromophenolphthaleins possible is much larger, viz. 54, but if, as suggested above, those which contain the *d*-position and not the *a*-position be eliminated, there remain 42 possible different spectra for the isomers. It will be sufficient to enumerate these, since their method of formation is obvious by what has gone before. They are:

a–b–c	*a–d–f*	*a–e–i*	*b–e–i*	*c–e–i*	*e–f–j*
a–b–d	*b–c–f*	*a–e–j*	*b–e–j*	*c–e–j*	*e–g–i*
a–c–d	*a–c–f*	*a–f–g*	*b–f–g*	*c–f–g*	*e–g–j*
a–d–e	*a–b–f*	*a–f–j*	*b–f–j*	*c–f–j*	*e–h–i*
b–c–e	*a–e–f*	*b–e–f*	*c–e–f*	*e–f–g*	*e–h–j*
a–c–e	*a–e–g*	*b–e–g*	*c–e–g*	*e–f–h*	*e–j–k*
a–b–e	*a–e–h*	*b–e–h*	*c–e–h*	*e–f–i*	*f–g–j*

Tribromophenolphthaleins.

Position of bromine atoms.	Method of formation.	Observed band-centre.	Calculated from position-law.
a–b–d } *a–c–d* }	3-4 (or 5)-6-tribromophthalic acid and phenol	} 576 inseparable	{ 575 { 582
f–g–j	Dibromo derivative of OBBA and orthobromphenol	577	577

Only these two could be prepared. In all the other cases tried the reaction went abnormally, giving substances which from the behaviour of phenolphthalein when heated with conc. H_2SO_4, and from their spectra, may be identified as isomeric varieties of dibromoxyanthraquinone.

There appear to be 80 possibilities for tetrabromophenolphthalein if the *d*-position is not counted unless the *a*-position is present. The first 7 are *abcd, abce, abcf, abde, abdf, acde* and *acdf*; then follow 28 made by combining the series *ef, eg, eh, ei, ej, fg, fh* with the series *ab, ac, ad, bc*; then follow 30 made by combining the series *efg, efh, efi, efj, egi, ehi, egj, ehj, fgi, fgj* successively with *a, b* and *c*. The remainder are *efg* combined with *h, i, j*;

efhi and *efhj*; *efi* combined with *j*, *k* and *l*; *egi* with *k* and *l* and *ehil*; and finally *fgij*, *fgik*, *fgil* and *fgjk*. Of this multitude of isomers only two could be prepared, viz.:

Tetrabromophenolphthaleins.

Position of bromine atoms.	Method of formation.	Observed band-centre.	Calculated from position-law.
a–b–c–d	Tetrabromphthalic acid and phenol	λ 583*	λ 583
f–g–j–k	Dibromo-OBBA and 2-6-dibromphenol, also by bromination of phenolphthalein	λ 584	λ 584

* The figures given in Part I, 1917, of this work for this substance and the thymol derivative are erroneous.

Taking account of the foregoing convention about the *d*-position, I find that the number of possible pentabromophenolphthaleins is 118. I have made and observed only those which are derived from the mono-derivatives by perbromination.

Pentabromophenolphthaleins.

Position of bromine atoms.	Source.	Observed band-centre.	Calculated from position-law.
a–f–g–j–k	*a*-monobromophenolphthalein	λ 597	λ 594
b (or *c*)–*f–g–j–k*	4-bromophthalic acid + phenol + bromine	λ 592	λλ 585 *b*, 592 *c*
e–f–g–j–k	*e*-monobromophenolphthalein	λ 602	λ 599

As regards the hexabromophenolphthaleins, the possible number is 134, taking account of the convention. Again I have only observed those obtainable by perbromination of lower brominated substances.

Hexabromophenolphthaleins.

Position of bromine atoms.	Source.	Observed band-centre.	Calculated from position-law.
a–d–f–g–j–k	*a–d*-dibromphenolphthalein	λ 606	λ 604
a–c–f–g–j–k	*a–c*-dibromphenolphthalein	λ 602	λ 602
b–c (?)–*f–g–j–k*	3rd dibromo-compound	λ 592	λ 593
c (?)–*e* (?)–*f–g–j–k*	Bromine on ordinary tetrabromo-compound*	λ 605	λ 607

* Only a trace obtained.

Heptabromophenolphthaleins.

Position of bromine atoms.	Source.	Observed band-centre.	Calculated from position-law.
a–b (?)–*d–f–g–j–k*	Tribromo-compound	λ 609 vague	{λ 605 *b* λ 612 *c*

The possible number is the same as that of the penta-derivatives, viz. 118. The possible number of octobromo-compounds is the same as that of the tetra-compounds, viz. 80, and so on with the nono-, deca- and hendeca-compounds. The substance *a–b–c–d–f–g–j–k* has been made in America, but I find it difficult to make a perfectly pure preparation. The figure given in Part I of this work, viz. λ 608, is certainly too low, since its band-centre should be at λ 613 or λ 614 by calculation.

A perchloro-derivative of phenolphthalein has been mentioned in Part IX, and is green in alkali with band-centre λ 642. The corresponding bromo-compound would have its band-centre at about λ 647.* The theory for a decabromophenolphthalein having all the positions except *a* and *d* occupied is λ 649, and it is reasonable to assume, from the analogy of phthalic acid, that the *a*- and *d*-positions would not be attacked by chlorine at the low temperature of boiling $CHCl_3$. This green substance is therefore *bcefghijkl*-decachlorophenolphthalein.

Another chlorine derivative which is new is monometachlorophenolphthalein, made from OBBA and metachlorphenol with H_2SO_4 at 100° C. Its band-centre was found to be at λ 564 only, and the band was broad. The theoretical figure is λ $568\frac{1}{2}$, and it is possible that the substance was contaminated with *o–p*-phenolphthalein, λ 559, arising from the OBBA alone. It is not possible to distinguish two band-centres unless they are at least 7 units in λ apart.

The corresponding monometaiodophenolphthalein was made in an analogous manner. Its band in alkali was at first broad, but on standing became narrow at λ $568\frac{1}{2}$ (theory $569\frac{1}{2}$). This substance was next perbrominated, and the penta-derivative (*f–g–j–k*-tetrabromo-*e*-iodophenolphthalein was found to have λ 600, which agrees with theory (554 + 30 + $15\frac{1}{2}$).

A penta-iodo-phenolphthalein was obtained by treating the barium salt of phenolphthalein with excess of warm solution of iodine in KI. Its band-centre was at λ 596, which differs from that of the *f–g–j–k*-tetriodo-compound (which is first formed) by 10 units. I infer, since iodination in the *a*-position

* From the law given in Part IX.

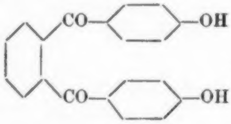
is very unlikely, that this substance is a mixture of the isomers *e-f-g-j-k* and *c-f-g-j-k* (theories λ 601 and λ 594).

Constitution of Phenolphthalein.

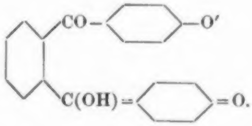
Having now exhibited the experimental evidence, I ask the reader to examine again the table on p. 130, which has been constructed from this evidence, and, confining his attention to the phthalic ring, particularly the positions *b* and *c*, to remember the result obtained in the study of benzaurine-derivatives (Part X). The latter were found to have a *negative* para-position: thus aurine, which is parahydroxybenzaurine, has λ 534, as against λ 553 for benzaurine; so the paracarboxylic acid of benzaurine (*ex* terephthalic acid and phenol) has λ 550, again showing a lowering caused by the para-position, its isomer, phenolphthalein having λ554. Now, as the table on p. 130 shows, this lowering does not occur when phenolphthalein is substituted in the para-position, when *b*-monobromophenolphthalein would have had λ 546 instead of λ 556 (colour-value = − 8 instead of + 1).

I infer from this therefore that the customary formulation of phenolphthalein (that on p. 130) is not the correct one. This formulation makes phenolphthalein to be simply the ortho- or A2-carboxylic acid of benzaurine, which, if true, should cause it to have a negative para-position as regards colour. In this connection also I may repeat what I have said before—that if phenolphthalein were really benzaurine-A2-carboxylic acid, it ought to exhibit the yellow colour of benzaurine derivatives when its alkaline solution is carefully neutralised (and then pass into a colourless lactone). Both phenolterephthalein and phenolsulphonephthalein change from pink to yellow on neutralising, and they are undoubtedly derivatives of benzaurine.

The customary formula for alkaline phenolphthalein, which has been accepted for thirty-five years, having been shown to be unsatisfactory, we may next consider the one which was current before 1885, viz:



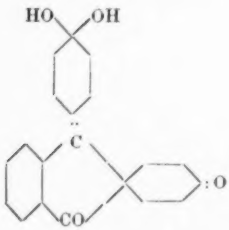
or when ionised,



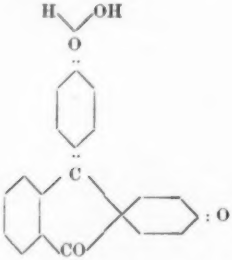
Phenolphthalein was then known as dioxyphthalophenone.

Now these formulæ were rejected about 1885 when it was discovered that diphenylphthalide had both phenyl rings on the same carbon-atom, and it was assumed, in some manner which I am unable to trace, that phenolphthalein is the dioxy-derivative of diphenylphthalide.

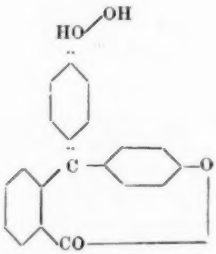
I should like therefore to put forward tentatively some of the other possible schemes, *e. g.*:



I.



II.



III.

These are combinations of the two former ideas, and depict phenolphthalein both as benzaurine-derivative and as a phthalophenone. They explain the easy formation of an oxime, and the easy change of the latter into oxybenzoylbenzoic acid and para-aminophenol.

I should add, of course, that I have no doubt that solid colourless phenolphthalein has the accepted lactone formula; the only question that is in doubt is the constitution of its coloured solutions in alkali, and I am fairly confident that the latter do not contain a free $-CO_2Na$ (or $-CO_2{}'$ ion), but are wholly phenolic in their character. The same applies to fluorescein, which may turn out to be merely an oxo-dioxyphthalophenone when in alkaline solution, although a triphenylcarbinol-derivative when solid.

A NOTE ON THE RELATIONSHIP BETWEEN CLOUD AND SUNSHINE.

By J. R. Sutton.

On a cloudless day a perfect sunshine recorder would show 100 per cent. of the optimum of sunshine. The ordinary sunshine recorders in use show less, because the record ceases when the sun is very low down, rising or setting.

The recorder in use at Kenilworth (Kimberley) is of the Jordan hemi-cylinder photographic type. The paper used with it is not sensitive to the rays from a low sun; and besides, it has not a good horizon, so that at the best it does not record more than 96 per cent. or so of what a perfect instrument would do. When the sun is high enough the instrument gives an excellent record. indicating with a considerable approach to exactitude, and with very little overlapping, the duration of the transit of the lower clouds over the sun. The higher, and thinner, clouds do not interrupt the sunshine very much.

Now any trace of sunlight on the sensitised paper is counted as sunshine; therefore if the sky were covered with thin cirrus all day, transmitting some sunshine, it would be possible to get this condition.

Sunshine	+	Cloud	=	Total
96	+	100	=	196 per cent.

Again suppose 40 per cent. of the sky to the southward to be covered with either cumulus or stratus all day, but no cloud to cross over the sun, then we should have—

Sunshine	+	Cloud	=	Total
96	+	40	=	136 per cent.

These are extreme cases of course, but we may nevertheless expect in general the monthly and yearly sums of sunshine and cloud to exceed 96 per cent.; and this proves to be the case. The following table shows the mean percentages of sunshine and cloud at Kenilworth for each month of the year, the cloudiness being deduced from daylight observations made at 800, 1100, 1400 and 1700 each day. The period from which the means are obtained is the twenty years 1900 to 1919.* Annual means for Hong-Kong, Córdoba and Mauritius are added for purposes of comparison. The Hong-Kong cloudiness is that of the mean of hourly observations, day and night, that of Córdoba is deduced from the daylight hours only, that of Mauritius from observations at 600, 900, 1300, and 1500.

* January, 1917, is omitted.

TABLE I.—*Monthly Means of Sunshine and Cloudiness at Kimberley.*

	Sunshine (%).	+	Cloud (%).	=	Total (%).
January	75·3	.	41·1	.	116·4
February	72·2	.	45·8	.	118·0
March	73·7	.	41·8	.	115·5
April	79·2	.	32·5	.	111·7
May	81·7	.	26·7	.	108·4
June	81·8	.	23·7	.	105·5
July	82·7	.	20·3	.	103·0
August	83·8	.	20·5	.	104·3
September	79·4	.	32·8	.	112·2
October	77·4	.	38·0	.	115·4
November	78·0	.	37·2	.	115·2
December	76·7	.	38·8	.	115·5
Year	78·5	.	33·3	.	111·8
Hong-Kong (year)	43·8	.	66·6	.	110·4
Córdoba ,,	63·0	.	48·0	.	111·0
Mauritius ,,	64·5	.	57·0	.	121·5

The October numbers in the Kimberley table are curious—a drop in the sunshine and a rise in the cloudiness as compared with September and November. This effect seems to be common to the central Tableland of South Africa. Leaving out of account the October irregularity there is a maximum of sunshine early in August and a minimum late in February, a maximum of cloudiness towards the middle of February and a minimum about the end of July, sunshine and cloudiness together being greatest about the first week in February, and least about the last week of July. Evidently the cloudiness decreases faster from its maximum than the sunshine increases from its minimum.

The table indicates roughly that the lower the percentage of sunshine and the higher the percentage of cloud, the higher the percentage of the sum of the two. This effect is analysed at greater length in Tables II and III at the end. Table II shows, for each grade of cloudiness from less than 15 per cent. to more than 51 per cent., the variations month by month in the percentages of sunshine plus cloud. In each month there is a strong trend to greater numbers as the cloudiness increases, while the annual means are in substantial agreement with the monthly means of Table I. Thus a cloudiness of 45·8 per cent. in February goes with 118 per cent. of sunshine plus cloud, as a cloudiness of 45 to 46 per cent. in Table II goes with 117 per cent. of sunshine plus cloud. Other corresponding numbers above :

Table I	23·7%	and	105·5%.
Table II	23 to 24%	and	105·1%.
Table I	37·2%	and	115·2%.
Table II	37 to 38%	and	115·9%.

TABLE II.—*Percentages of Sunshine plus Cloud compared with Percentages of Cloud.*

Cloud (%).	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	
													Times.	Mean.
15 and less	—	—	—	—	3 100	1 100	6 97	6 100	2 100	—	—	—	18	99·1
16 to 20	—	—	—	1 100	3 106	4 104	4 105	3 104	—	—	1 109	—	16	104·6
21, 22	—	—	—	—	1 105	4 105	2 103	2 104	—	1 107	—	—	10	104·4
23, 24	—	—	—	3 109	—	3 105	1 106	2 100	1 103	—	—	—	10	105·1
25, 26	—	—	—	1 108	2 106	1 109	2 106	2 106	3 111	1 111	1 111	2 108	15	108·3
27, 28	1 111	—	2 110	2 110	2 112	2 104	—	1 111	2 111	—	2 110	—	14	109·6
29, 30	—	1 110	—	—	4 109	2 112	3 106	3 110	1 111	2 116	1 110	1 110	18	110·0
31, 32	3 111	—	—	1 114	—	3 106	1 109	—	1 115	—	—	—	9	110·0
33, 34	1 112	3 114	2 111	5 114	—	—	—	—	2 114	1 112	1 115	1 116	16	113·5
35, 36	1 111	—	1 114	—	1 112	—	—	1 111	—	4 114	4 115	2 114	14	113·7
37, 38	2 116	—	3 117	2 112	—	—	—	—	1 114	1 118	2 115	2 119	13	115·9
39, 40	5 115	3 114	1 113	1 114	1 113	—	1 108	—	2 117	3 116	1 115	3 118	21	115·0
41, 42	—	—	1 113	2 114	1 120	—	—	—	—	1 117	2 118	4 114	11	115·3
43, 44	—	1 119	1 110	1 115	1 117	—	—	—	1 118	2 115	—	1 118	8	116·0
45, 46	1 118	1 118	—	—	1 113	—	—	—	1 116	1 117	3 117	2 119	10	117·0
47, 48	1 122	3 119	3 120	1 117	—	—	—	—	2 116	1 119	—	2 120	13	119·0
49, 50	—	4 118	5 119	—	—	—	—	—	1 120	1 116	—	—	11	118·3
51 and more	4 118	4 125	1 113	—	—	—	—	—	—	1 122	2 126	—	12	121·7

TABLE III.—*Percentages of Sunshine plus Cloud compared with Percentages of Sunshine.*

Sunshine (%).	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year. Times.	Year. Mean.	Year. Smoothed Mean.
66 and less	1 119	3 122	2 111	—	—	—	—	—	1 112	—	1 111	—	8	116·4	—
67	1 126	1 115	3 116	—	—	—	—	—	—	2 113	—	—	7	116·6	115·8
68	—	1 117	—	—	1 113	—	1 108	—	—	—	—	—	3	112·7	115·4
69	—	1 118	1 118	1 111	—	—	—	—	—	—	—	—	3	115·7	116·5
70	—	1 127	1 118	2 113	—	—	—	—	—	—	1 127	—	5	119·4	117·5
71	2 117	1 119	1 119	—	—	—	—	—	2 118	1 122	—	2 112	9	117·1	116·9
72	—	3 121	1 113	1 115	—	—	1 101	1 95	1 120	2 118	1 124	4 118	15	115·9	116·3
73	1 118	—	1 113	—	2 115	—	—	—	—	—	1 119	—	5	116·0	114·9
74	1 122	2 114	1 122	1 114	—	3 104	—	—	1 113	—	—	2 117	11	113·0	115·5
75	4 118	—	—	1 117	—	—	—	—	1 118	1 117	1 120	2 117	10	117·9	114·8
76	2 113	1 119	1 126	—	—	1 108	—	2 108	1 110	1 115	3 116	—	12	113·9	115·2
77	—	3 117	—	—	2 110	—	1 109	—	1 114	3 117	2 115	1 113	13	114·3	113·8
78	2 114	—	2 114	1 116	3 111	—	—	—	—	3 114	2 113	—	13	113·3	112·6
79	2 111	1 113	2 113	1 112	1 109	1 102	1 108	1 105	—	1 114	—	2 111	13	110·3	111·9
80	—	1 110	2 117	3 108	1 110	—	2 107	—	2 105	1 116	2 113	2 119	16	111·4	109·9
81	1 113	—	1 118	2 114	1 109	4 104	3 100	2 103	1 111	1 118	1 110	2 113	19	108·3	109·7
82	1 119	—	—	—	—	3 106	2 100	2 109	—	—	1 115	2 118	11	109·5	110·0
83	1 111	1 116	—	3 113	1 105	1 109	1 106	1 105	3 118	1 113	2 115	—	15	112·5	110·2
84	—	—	1 112	1 100	1 109	2 111	—	4 106	1 109	—	—	1 110	11	107·8	109·5
85	—	—	—	1 112	—	—	2 102	1 105	1 99	2 109	1 111	—	8	106·1	107·4
86	—	—	—	1 109	—	1 102	—	—	2 112	—	—	—	4	108·8	106·8
87	—	—	—	—	3 108	2 106	1 107	—	1 100	—	—	—	7	106·4	105·9
88	—	—	—	—	1 95	—	—	2 103	—	—	—	—	3	100·7	105·1
89	—	—	—	—	1 107	1 111	2 98	—	1 114	—	—	—	5	105·8	104·8
90	—	—	—	—	—	1 100	1 108	2 102	—	1 120	—	—	5	106·4	105·8
91 and more	—	—	—	1 114	2 102	—	2 98	2 100	—	—	1 109	—	8	103·1	104·4

Table III shows, for each grade of sunshine from less than 66 per cent. to greater than 91 per cent., the variations month by month in the percentages of sunshine plus cloud. In each month there is a tendency to smaller numbers as the sunshine increases ; but the annual means (especially when they are smoothed in threes, as in the last column), although they establish a gradual fall, do not give the same rate of fall as Table I. Thus in Table III 70 per cent. of sunshine corresponds to 117·5 per cent. of sunshine plus cloud, while 89 per cent. of the one corresponds to 104·8 per cent. of the other—that is, a rising range of 19 per cent. of the one corresponds to a falling range of 12·7 per cent. of the other. As against this a rising range of about 11 per cent. of sunshine in Table I corresponds to a falling range of somewhere about 15 per cent. of sunshine plus cloud.

We may judge from these results that a sunshine recorder is not (as it is sometimes asserted to be) an automatic device for determining the average cloudiness of the sky. Both sunshine and cloudiness have common elements it is true, yet they are no more convertible terms than are, say, the temperatures of the air and of radiation, or, better still, than are evaporation and rainfall.

Greatest and least monthly percentages of sunshine recorded and cloudiness observed, 1900 to 1919, are given in Table IV. Here the cloudiness is deduced from six observations a day, two being night hours.

TABLE IV.—*Monthly Maxima and Minima of Sunshine and Cloud.*

	Sunshine.			Cloud.		
	Max.	Min.	Range.	Max.	Min.	Range.
	(%).	(%).	(%).	(%).	(%).	(%).
January	83	63	20	59	26	33
February	83	59	24	65	31	34
March	84	62	22	52	26	26
April	91	69	22	43	13	30
May	94	68	26	43	5	38
June	90	74	16	31	9	22
July	92	68	24	35	3	32
August	95	72	23	33	5	28
September	89	65	24	45	11	34
October	90	67	23	48	22	26
November	92	66	26	55	16	39
December	84	71	13	48	25	23

Thus there has been an August (1906) with almost uninterrupted sunshine, and a July (1914) with only 3 per cent. of cloud. June has never had more and February never less than 31 per cent. of sky clouded—the June maximum in 1913, the February minimum in 1919.

A POSSIBLE LUNAR INFLUENCE UPON THE VELOCITY OF THE WIND AT KIMBERLEY.

(Second Paper.)

By J. R. Sutton.

(With one Text-figure.)

In a previous paper under the same title reasons were given for presuming that the moon must exert a certain amount of influence upon the movements of the lower air. Tables were also given showing the variation in the velocity of the wind during the course of the lunar day in general, and also for the moon south and moon north of the equator. From the results of the investigation a mean diurnal range of velocity, attributable to the moon, of 0·2 mile an hour was deduced, but much greater ranges when the observations were separated into sets for moon south and moon north. My opinion at the time was that these ranges were greater than should have been expected *à priori*. In the present discussion, however, the problem has been carried a step further, and even greater ranges are deduced.

We have to do now with the variations in the velocity of the wind when the moon is near perigee. The period covered is nearly twenty-two years, comprising 288 perigees, from April, 1897, to January, 1919—that is to say, it covers some eight years more of time than the first paper did. Perigee was selected partly because some rigid standard of reference was desirable, partly because a somewhat greater effect might be anticipated from the moon's contiguity, and chiefly for reasons to be developed as we proceed.

The tabular numbers in the table have been computed as follows:

Let V_n be the velocity of the wind at any civil hour n;

v_n the mean velocity for the same hour of the same month.

Then $V_n - v_n + 10$ is a quantity to be transferred to its proper hour of the lunar day, the numeral 10 being added in every case in order to obviate the necessity for the use of plus and minus signs. A further convenience is that in the process of taking means of the quantities $V - v + 10$, anything greater than 10 is positive, anything less is negative. The meaning, therefore, of the numbers in the table is that the normal hourly means are supposed to lie upon the straight line $z = 10$, and that the tabular numbers are as deviations from that line. This plan eliminates the possibility of any intrusion of solar or other periodicities—which are especially liable to intrude where such things as perigee are concerned, seeing that at perigee the moon culminates most often in the hours about

noon and midnight, and seldom at VI or XVIII. The observations made use of are those for the day upon which perigee occurred, together with the day before and the day after, 864 days in all, necessitating considerably over 20,000 simple subtraction sums. The labour is almost prohibitive.

In the table on p. 146, column 1 indicates the hours of the lunar day, U.M.P. being lunar noon, the mean of the first and twenty-fifth being accounted lunar midnight, or L.M.P.

Column 2 gives the hourly means of the deviations $V - v + 10$ for all the perigee periods as defined above.

Column 3 gives the means of the deviations when the moon near perigee culminates between X and XIV. These we call "noon" culminations.

Column 4 the same for the four hours XXII to II. These we call "midnight" culminations.

Column 5 the same for the remaining hours. These we call "horizon" culminations, since the horizon is nearly the sun's mean position for these hours.

All the tabular numbers have been smoothed in threes by Bloxam's process in order to straighten out minor asperities. Such smoothing is perhaps open to criticism as unnecessary, and, at any rate, it diminishes somewhat the range of the velocity deviations attributable to the moon.

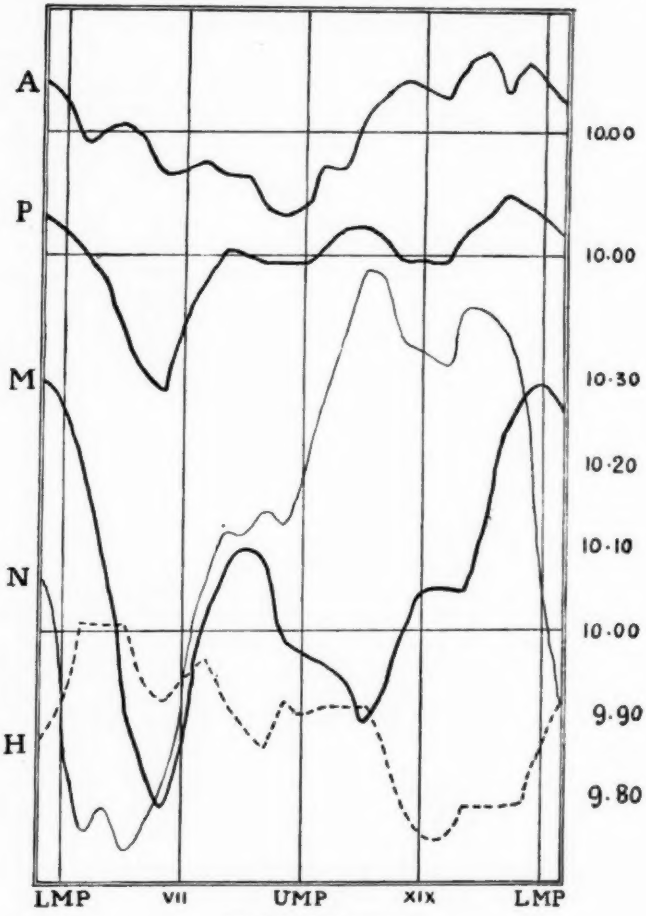
According to column 2 there is one principal maximum and one principal minimum of velocity deviation, the former about XXIII, and the latter near moonrise, with a range of 0·235 mile an hour. Secondary maxima occur at IX and XVI; secondary minima at XII and XX.

It is interesting to compare this perigee range and the range given in the previous paper (which we may regard as the range for the moon's mean distance) with the moon's least and mean distance from the earth. Calling the mean distance unity, the least distance is about 0·933, so that the ratio of the cubes of the distances is as unity is to 0·81. Now the ratio of the ranges of wind velocity for mean and for perigee distances is as unity is to 1·175. or, say, 0·85 to 1: that is, the ratio of the ranges of velocity is very nearly the same as the inverse ratio of the cubes of the moon's distances. And it would be still more nearly the same if we were to take the moon's mean distance for the three days about perigee.

Column 3, derived from 226 noon perigees, and column 4, derived from 269 midnight ones, give two remarkable curves. With minor fluctuations the former has a minimum at IV and a maximum at XVI, with a range of 0·7 mile an hour; whereas the latter has definite double maxima and minima (like a diurnal atmospheric pressure curve) at X and L.M.P. and at VI and XVI, with a whole range of 0·5 mile an hour. Column 5 gives a relatively featureless curve, excepting that it vibrates practically in opposite phases to that of column 3, with a range of 0·25 mile an hour. These are large ranges, but

they go to confirm those previously found. The mean values at the foot of the columns are very curious, and possibly significant.

The tabular numbers are shown diagrammatically in the figure, together



Wind-deviation curves.

with the curve for all the observations described in the previous paper. All the curves have something in common, and nearly every turning-point on any one curve has its corresponding analogy on the others. A complete explanation of them all is not yet to be attempted; but a more or less

tentative and partial one may be hazarded for some outstanding features. For example, there are differences between the noon, midnight and horizon curves which appear to arise largely, if not entirely, from the diurnal variation of wind direction. This diurnal variation of direction has been

Table Showing the Variation of Wind Velocity in Miles an Hour during the Course of the Lunar Day at Perigee.

Hour.	Mean perigee.	Noon perigee.	Midnight perigee.	Horizon perigee.
L.M.P.	10·024	9·915	10·265	9·916
II	10·001	9·766	10·185	10·012
III	9·975	9·783	10·089	10·009
IV	9·910	9·735	9·918	10·011
V	9·862	9·759	9 844	9·939
VI	9·843	9·804	9·780	9·912
VII	9·907	9·913	9·868	9·932
VIII	9·972	10·032	9 996	9·965
IX	10·007	10·114	10·069	9·917
X	10·002	10·115	10·098	9·881
XI	9·995	10·143	10·080	9·861
XII	9·994	10·125	9·989	9·917
U.M.P.	9·995	10·179	9·974	9·896
XIV	10·016	10·252	9·963	9·909
XV	10·039	10·358	9·945	9·912
XVI	10·040	10·431	9·891	9·910
XVII	10·026	10·426	9·927	9·856
XVIII	9·995	10·346	9·995	9·782
XIX	9·995	10·330	10·045	9·754
XX	9·992	10·317	10·049	9·753
XXI	10·025	10·385	10·047	9·784
XXII	10·048	10 386	10·122	9·781
XXIII	10·078	10·359	10·236	9·786
XXIV	10·067	10·268	10·282	9·787
L.M.P.	10·050	10·056	10·300	9·863
Mean	9·994	10·132	10·036	9·882
Range	·235	·696	·502	·259
No.	864	226	269	369

described in a preliminary way some years ago (J. R. Sutton, "The Winds of Kimberley," 'Trans. Phil. Soc. S.A.,' 1900). Generally speaking, we may say that the normal resultant winds of Kimberley have northerly components from sunrise to sunset, and southerly ones during the night; westerly components from about IX to XX, and easterly ones from XX to IX. Thus when the moon (being north of Kimberley) near perigee culminates at noon, the

winds of Kimberley during the day are moving normally down the gradients of pressure set up by the lunar tide in the air, thus augmenting their speeds, whereas during the night they are moving up the gradients and thus diminishing their speeds. A similar sort of explanation applies to the "horizon" curve, and to a good portion of the "midnight" curve; but it gives no adequate reason for the minimum near moonrise common to all the curves, and which is probably of a more general character. Thus the curves shown in the diagram are largely due to the superimposition of the lunar air tide upon the diurnal variation of wind direction.

The acceptance of this explanation would demand that the velocity deviation curves of no two places even on the same circle of latitude would be quite alike, as the lunar air tide (to which they are in great part subject) is. Even so the deviations of velocity cannot be regarded as mere surface phenomena, but rather as the outcome of conditions common to the whole depth of the atmosphere.

In a later paper I hope to discuss the velocity deviations for the moon in apogee. My wife, as usual, has checked off the averages: without her help the investigation could not have been undertaken.

In the diagram A is the mean curve for all the observations used in the previous paper; P, M, N, H are the mean, "midnight," "noon," and "horizon" perigee curves of columns 2, 4, 3 and 5 respectively.

SOUTH AFRICAN ALCYONACEA.

By J. Stuart Thomson
(From the Department of Zoology, Victoria University of Manchester).

(With Plates V and VI and 5 Text-figures.)

Foreword.—"The species has its adventures, its history and drama, far exceeding in interest and importance the individual adventure."—'God the Invisible King,' H. G. Wells, 1917.

In 1904 Hickson, in a paper on the "Alcyonaria of the Cape of Good Hope," gave the following list of Stolonifera and Alcyonacea which up to that time had been recorded from South African seas:

Sub-Order STOLONIFERA.

Family CLAVULARIIDAE.

Anthelia capensis, Studer. 33° S., 17° W., 50 fathoms.

Sub-Order ALCYONACEA.

Family XENIIDAE.

Heteroxenia capensis, Hickson. False Bay, 20 fathoms.

Family ALCYONIIDAE.

Alcyonium pachyclados, Klunzinger. Off Cape St. Blaize, etc., 15–18 fathoms.

Alcyonium antarcticum, Wright and Studer. Off East London, 45 fathoms.

Alcyonium purpureum, Hickson. Mossel Bay, etc., shore.

Acrophytum claviger, Hickson. Algoa Bay, 26 fathoms.

Sarcophytum trochiforme, Hickson. Off East London, 45 fathoms.

Anthomastus grandiflorus, Verrill. Off Cape Recife, 256 fathoms.

Family NEPHTHYIDAE.

Eunephthya thyrsoides, Verrill. False Bay, 20 fathoms.

In 1910 I published a paper on the Alcyonaria of the Cape of Good Hope and Natal containing descriptions of the following:

FAMILY ALCYONIIDAE.

Bellonella Studeri, St. Thomson. St. Francis Bay, near Port Elizabeth. 23–25 fathoms.

Bellonella rubra, Brundin. Locality not recorded.

Metalcyonium clavatum, Pfeffer. From Umhloti river mouth, 40 fathoms, and Tongaati river mouth, 36 fathoms.

Metalcyonium natalense, St. Thomson. Umhloti river mouth (Natal), 39–40 fathoms.

METALCYONIUM PATAGONICUM, May.

Syn., *Metalcyonium variabile*, var. *durum*, St. Thomson.

Off Sandy Point, 51 fathoms; off Cape Morgan, near East London, 77 fathoms; off Tugela River mouth (Natal), 65–70 fathoms; off Amatikulu River mouth (Natal), 62 fathoms.

Alcyoneum purpureum, Hickson. Between Roman Rock and Cape Recife, Kalk Bay; Gordon's Bay, etc., a common littoral form.

Alcyonium Fauri, St. Thomson. Off Cape St. Blaize, near Mossel Bay, 36 fathoms.

Alcyonium pachyclados, Klunzinger. Off Gonubie River (near East London), 20 fathoms; off Algoa Bay, etc.

Alcyonium rotiferum, St. Thomson. Off Keiskamma Point.

Malacacanthus rufus, St. Thomson. Off Seal Island, False Bay, 11–33 fathoms.

FAMILY NEPHTHYIDAE.

Capnella rugosa, Kük. Off Gonubie River, near East London, 20 fathoms.

Capnella Gilchristi, St. Thomson. Off Cape Morgan, 47 fathoms.

Eunephthya thyrsoides, Verrill. Off Cape Morgan, 45 fathoms.

At first my work on the specimens described or recorded in the present paper was not promising in the way of revealing interesting forms, but later it brought out the occurrence in the collection of several specimens of some phylogenetic interest.

The occurrence of *Scleranthelia musiva*, Studer, off Cape Morgan is interesting as affording me the opportunity of confirming the work of my revered teacher, Prof. Th. Studer, of Berne. The authorities Hickson, Schenk and May were in error in regard to the position of *Scleranthelia*. *Scleranthelia* was first placed by Studer with the *Clavulariidae*, but this classification was later disputed by Hickson and others. In 1890 Studer emphasised his former statement that *Scleranthelia* belonged to the family *Clavulariidae*, and I now have pleasure in supporting the position of the Bernese "savant."

The occurrence of *Metalcyonium molle*, Burchardt, in the collection is also interesting. This species was first collected off Amboina, and described as being entirely without spicules, but the specimen from South Africa shows

a few spicules. Another author has suggested that the apparent absence of spicules may be due to bad preservation.

Alcyonium sarcophytoides, Burchardt, a species which was firstly found in Austro-Malayan seas, is another interesting form. This form has many points of agreement both with *Alcyonium* and *Sarcophytum*. It differs, however, from the genus *Alcyonium* in having parts which are extremely like rudimentary siphonozooids, and would thus come near *Sarcophytum*. The question may be asked whether the form named *Alcyonium sarcophytoides* is an *Alcyonium* on the up-grade or a *Sarcophytum* on the down-grade. I have explained why the first of these suppositions appears the more probable.

A very abundant form in South African waters is that which I now term *Metalcyonium variabile*. There is no doubt that this is the same species as that described by Hickson as *Alcyonium antarcticum*, W. and S., but which is not really identical with the "Challenger" form. I have had the opportunity of seeing the "Challenger" example of *Alcyonium antarcticum* in the Natural History Museum, South Kensington. A large number of specimens of *Metalcyonium variabile* are in the collection, and by this means I have been able to observe its extreme variability.

The forms which I described in 1910 as *Metalcyonium natalense* I now recognise as identical with the species described by Hickson as *Acrophytum claviger*.

The re-occurrence of *Malacacanthus rufus*, St. Thomson, is interesting. This form is apparently non-spicular, but lives in sand, and is protected by adherent foreign bodies. On the first occasion I was not quite satisfied as to this species really being non-spicular, as accidents in preservation in rough seas have always to be taken into account, but these additional specimens show a non-spicular condition.

My work on *Sinularia unilobata* leads me to remark that while the name *Sclerophytum* appears at first sight an extremely good one, yet this genus is identical with *Sinularia* and the latter name has priority. It also appears that the genera *Lobophytum*, *Sarcophytum* and *Sinularia* (*Sclerophytum*) are not widely separated.

In this paper, which includes all the specimens of Cape Stolonifera and Alcyonacea in my hands, but which excludes the Nephthyidae, the latter having been sent to Dr. W. D. Henderson, I record or describe the following 25 species, of which 5 are new:

Family CLAVULARIIDAE.

Clavularia cylindrica, Wright and Studer.
Clavularia elongata, Wright and Studer var. *africana*, n. var.
Scleranthelia musiva, Studer.

Family TELESTIDAE.

Telesto arborea, Wright and Studer.

FAMILY XENIIDAE.

Xenia florida (Lesson), Dana.

FAMILY ALCYONIIDAE.

Alcyonium glomeratum, Hassall.
Alcyonium pachyclados, Klunzinger.
Alcyonium purpureum, Hickson.
Alcyonium Sollasi, Wright and Studer.
Alcyonium sarcophytoides, Burchardt.
Alcyonium (Erythropodium) reptans, Kükenthal.
Alcyonium (Erythropodium) foliatum, sp. n.
Alcyonium (Erythropodium) membranaceum, Kükenthal.
Alcyonium (Erythropodium) Wilsoni, sp. n.
Alcyonium (Metalcyonium) novarae, Kükenthal.
Metalcyonium molle, Burchardt.
Metalcyonium variabile.
Syn. *Alcyonium antarcticum*, Hickson.
Syn. *Metalcyonium patagonicum*, May (St. Thomson).
Metalcyonium lanceatum, sp. n.
Sarcophytum trochiforme, Hickson.
Syn. *Anthomastus trochiforme*, Kükenthal.
Anthomastus granulosus, Kükenthal.
Anthomastus elegans, Kükenthal.
Acrophytum claviger, Hickson.
Bellonella Studeri, St. Thomson.
Malacacanthus rufus, St. Thomson.
Sinularia (Sclerophytum) unilobata, sp. n.

FAMILY CLAVULARIIDAE.

CLAVULARIA CYLINDRICA, Wright and Studer.

In the "Pieter Faure" Collection there is a specimen of this species from shallower water than that in which the "Challenger" form was obtained, the latter being procured off Nightingale Island, Tristan da Cunha, at a depth of 100–150 fathoms.

Locality, etc.—"Pieter Faure," No. 15896. Seal Island, S.W. ½ S. ¾ miles Depth, 11 fathoms. Collected by dredge. Nature of bottom, rocks. Date of collection, November 12, 1902.

More than thirty species of the genus *Clavularia* have been described, and Thomson and Henderson, who have contributed a very useful diagnostic table of the species of this genus, hold that "the species of *Clavularia* are in a state of flux."

Kükenthal has endeavoured to distinguish the genus *Clavularia* from the

genus *Anthelia* by certain characters, and regards the former as a deep-water, the latter as a shallow-water form. When, however, one applies Kükenthal's own distinctions, one is at once landed in difficulties. The two forms which I here record from South African waters are undoubtedly true species of *Clavularia* according to Kükenthal's diagnosis of this genus and yet both of those occur in shallow water. It appears to me that this distinction of shallow-water forms as belonging to the genus *Anthelia* and deep-water specimens as pertaining to the genus *Clavularia* is not tenable. I have examined specimens of Hickson's which are undoubtedly species of *Clavularia* as distinguished by Kükenthal's characters of that genus, and yet they are placed in his list as species of *Anthelia* apparently mainly for the reason that they occur in shallow water. In the same year as Kükenthal's memoir on the "Valdivia" Alcyonacea was published, Thomson and Henderson described a number of shallow-water forms from Zanzibar as belonging to the genus *Clavularia*.

CLAVULARIA ELONGATA, Wright and Studer, var. *africana*, n. var.

This specimen is closely allied to *Clavularia elongata*, W. and S.; the latter was, however, collected in deep water (1000 fathoms) off the Azores.

Locality, etc.—"Pieter Faure," No. 9065. Cape Infanta, N. ½ W. 13½ miles. Depth, 42 fathoms. Collected by shrimp trawl. Nature of bottom, mud and sand with black specks. Date of collection, July 13, 1900.

SCLERANTHELIA MUSIVA, Studer.

(Plate V, fig. 1.)

The specimen consists of hard, encrusting stolons which are continued into a slightly raised mound-like mass on which there are 7–9 hard-walled polyps. The encrusting part rests on a hard mass of stones and fragments of shells, on which there are also Bryozoa. The specimen is about 15 mm. in height and 14 by 11 mm. in diameter. The colour is pale yellow. The encrusting part rises at the most to a height of 3 mm. from the attaching surface. The polyps are sometimes slightly curved, have a fairly uniform diameter throughout, namely from 3–4 mm., but are slightly narrower at their apices; some are 13 mm., others 4 mm. in length. They are very rigid, and covered by scale-like or pavement-like spicules. The polyps are sometimes in juxtaposition; others are separated from one another by an interval of 3–4 mm. The polyp-cavity is relatively small, with a diameter of about 1·2 mm.; this is occasioned by the thickness of the polyp-wall and its spicules, the former being about ¼–½ a millimetre in thickness.

The characteristic scale-like plates on the surfaces of the polyps are of the most varied sizes and shapes; their outer surfaces are densely covered with tubercles. They are sometimes long and spindle-like, or they may be broad plates, a small one 0·4 mm., a large one 1·20 mm. in length. These

spicules on the surfaces of the polyps are situated closely adjoining one another, and usually with their long axes parallel with the long axis of the polyp; they apparently tend to become broader towards the polyp-base. At the apex the arrangement of the spicules produces an 8-rayed appearance when the oral aperture is open, but in the closed or retracted condition the spicules are folded down with the ectoderm, and thus completely protect the internal parts of the polyp, one of the marked features of this species being the efficient protection of the polyps. The anthocodiae were retracted in all cases; this part also has spicules, but of quite a different character, namely, they are mostly long, simple spindles with small processes, but some are club-like; the largest are about 0·40 × 0·03. The specimen appears to

FIG. 1.—Spicules of *Scleranthelia musiva*, Studer.

agree well with Wright and Studer's definition of Studer's genus *Scleranthelia*, and the figure of a spicule as given by Studer is similar to some of the characteristic spicules of my forms.

The genus *Scleranthelia* was first placed by Studer (1878) among the Clavulariidæ; later Hickson and Schenk classified it as an Alcyonid, while May regarded it as belonging to the family Telestidae. At a later period (1890) Studer emphasised his original statement that *Scleranthelia* belongs to the family Clavulariidæ, and his original idea is apparently correct that it affords some measure of transition between the Clavulariidæ and the Telestidae. This view is apparently now also held by Kükenthal.

Locality, etc.—"Pieter Faure," No. 13165. Cape Morgan, N. ½ W. 10½ miles. Depth, 77 fathoms. Collected by dredge. Nature of bottom, rock and broken shells. Date of collection, July 26, 1901.

Family TELESTIDÆ.

Telesto arborea, Wright and Studer.

This species was first collected during the voyage of the "Challenger" at Station 90, north of Torres Strait and south of the Arrou Islands; later it has been recorded from Zanzibar.

Locality, etc.—"Pieter Faure," No. 12310. Port Shepstone, N. 8 miles. Collected by dredge. Depth, 36 fathoms. Nature of bottom, broken shells. Date, March 14, 1901.

Family XENIIDÆ.

Xenia florida (Lesson), Dana.

The specimen is not complete, but I have little hesitation in identifying it as belonging to the above species. I agree with May in holding that *Xenia plicata*, Schenk, and *Xenia florida*, Lesson (Dana), are of the same species. The specimen agrees well with the description given by Schenk of *Xenia plicata*. The species has been previously recorded from off New Ireland and New Hanover, off Port Denison, off the North Coast of the Kei Islands, off the Fiji Islands, off Tamatave (Madagascar), and off Ternate.

Locality, etc.—"Pieter Faure," No. 14373. Cape St. Blaize, N.E. by N. ¼ N. 10–11 miles. Depth, 110 fathoms. Collected by dredge. Nature of bottom, broken shells, rocks and corals. Date, February 21, 1902.

Family ALCYONIIDÆ.

Alcyonium glomeratum, Hassall.

A yellow specimen of tough texture (when preserved), surface much wrinkled. From a slight encrusting part attached to a stone two finger-like lobes arise. Calyces large and prominent, anthocodiae white. After a comparison of this form with specimens of this species from the English Channel and from Talila Bay, New Britain, I have little doubt of this identification. The European specimens have been said to have no dumb-bell-shaped spicules, while those from new Britain possess them; in this respect my specimen agrees with the latter rather than with the former.

Locality, etc.—"Pieter Faure," No. 10783. Cape Natal, W. ¾ N. 12½ miles. Collected by large dredge. Nature of bottom, sand and shells. Depth, 85 fathoms. Date, December 17, 1900.

Alcyonium pachyclados, Klunzinger.

(Plate V, figs. 6, 7, 8.)

Specimen 50 mm. in length, length of more or less cylindrical stalk 28 mm.; diameter of stalk 9–14 mm. Ground colour of colony brick-red,

anthocodiae whitish or yellowish. At first sight there is little resemblance between this specimen and those previously described by Hickson and by myself. It affords a good example of the great extent to which an Alcyonarian species may vary in superficial appearance. The length and thickness of the stalk is noteworthy; the latter resembles *Anthomastus grandiflorus* in form and colour. For the sake of illustrating specific variation the coloured figure is of interest. *Alcyonium pachyclados* must be regarded as a fairly common South African form.

Locality, etc.—"Pieter Faure," No. 13078. Hood Point north, 5½ miles. Depth, 42 fathoms. Collected by dredge. Nature of bottom, sand and shells. Date of collection, July 17, 1901.

ALCYONIUM PURPUREUM, Hickson.

This species has previously been described from Cape Colony by Hickson and by myself. It is a comparatively common, shallow-water South African form.

Localities, etc.—"Pieter Faure," No. 11842. Durnford Point, N.E. by E. 9 miles. Depth, 13 fathoms. Collected by dredge. Nature of bottom, sand and shells. Date of collection, Feburary 8, 1901.

"Pieter Faure," No. 13288. Cove Rock, N.E. by E. ½ E. 4½ miles. Depth, 22 fathoms. Collected by dredge. Nature of bottom, rocks and broken shells. Date of collection, August 6, 1901. A young specimen reminding one at first sight in its mode of growth of those forms which have been more recently relegated to the genus *Erythropodium*.

"Pieter Faure," No. 15969. Zwart Klip, N. by E. 2 miles. Depth, 13 fathoms. Collected by dredge. Nature of bottom, broken shells. Date of collection, December 17, 1902.

"Pieter Faure," No. 10880. Umhloti River mouth, N. by W. ½ W. 8½ miles. Depth, 40 fathoms. Collected by large dredge. Nature of bottom, sand and shells (hard ground). Date, December 18, 1900.

"Pieter Faure," No. 11106. Illovo River mouth, N.W. by N. ¾ N. 5 miles. Depth, 27–30 fathoms. Collected by large dredge. Nature of bottom, broken shells. Date, December 31, 1900.

"Pieter Faure," No. 13502. Cape Morgan, W. ½ S. 4 miles. Depth, 17 fathoms. Nature of bottom, rocks. Date of collection, August 5, 1901. Two young specimens, one growing on a shell of *Kraussina rubra* and the other on an alga, whose general appearance is so divergent from that of the normal encrusting form that they are not at first sight recognisable as belonging to this species.

"Pieter Faure," No. 12389. Itongazi River, N.W. ¾ W. 3 miles. Depth, 25 fathoms. Collected by dredge. Nature of bottom, rocks and stones. Date of collection, March 14, 1901.

"Pieter Faure," No. 86. Mossel Bay. Depth, 20 fathoms. Collected by shrimp trawl. Date of collection, June 24, 1898.

ALCYONIUM SOLLASI, Wright and Studer.

The specimen is fragmentary, but apparently agrees in form with those collected during the voyage of the "Challenger." The form and size of the spicules are also similar.

The "Challenger" specimens were collected at the entrance to the Straits of Magellan at a depth of 55 fathoms, and were, as is the case with the Cape specimen, embedded in a mass of hardened sand and mud.

Locality, etc.—"Pieter Faure," No. 2034. Green Point Lighthouse, S. $\frac{1}{4}$ W. $2\frac{1}{2}$ miles. Depth, 22 fathoms. Nature of bottom, stones and shells. Date of collection, March 5, 1900.

ALCYONIUM SARCOPHYTOIDES, Burchardt.

This species is represented in the collection by one specimen in the form of a large, fleshy, plump mass, irregularly cylindrical in shape and yellow in colour. It is 78 mm. in length, and demarcated into a basal trunk-like part and an upper zooid-bearing portion, the surfaces of both of which are fairly rough. The basal part is 37 mm. in length and about 29 mm. in diameter. The upper is 41 mm. in length and about 29 mm. at its greatest diameter. The diameter at the constriction between the basal and upper part is 15 by 16 mm. The basal part has a very irregular appearance, showing deep depressions on its surface. The upper part is not so irregular, the depressions being smaller, but at the apex there is a tendency towards the formation of lobes. On the surface of the upper part the anthozooids appear as 8-lobed elevations with white anthocodiae. The specimen agrees fairly well with the description of *Alcyonium sarcophytoides* given by Burchardt, except that his specimen appears to have been a younger form, that "Zwirnrollen" are not entirely absent but rare in the zooid-bearing part of my specimen, and that in this case one might almost speak of a slight calyx.

The specimen is extremely interesting in the occurrence of parts which resemble rudimentary siphonozooids, but regarding which I am in agreement with Burchardt in having the utmost difficulty in determining indubitably as siphonozooids. In *Sclerophytum polydactylum* Pratt has also described similar, apparently degenerate siphonozooids which are coeca from the superficial transverse canals. I have had the opportunity of examining Pratt's slides of degenerate siphonozooids in *Sclerophytum polydactylum*, and it is obvious that in *Alcyonium sarcophytoides* one has a practically similar condition. The species is of great interest as pointing towards the fact that the genera *Alcyonium, Sarcophytum* and *Sclerophytum* (*Sinularia*) are probably not widely separated. Burchardt remarks that it is difficult to say whether

the species should be named *Alcyonium sarcophytoides* or *Sarcophytum alcyonoides*, whether it should be regarded as a progressive *Alcyonium* or a degenerate *Sarcophytum*. The occurrence of "Zwirnrollen" in abundance in the basal part and of a few in the zooid-bearing portion, a form of spicule which does not occur in the genus *Sarcophytum*, appears to be against the supposition that this species is atavistic, and rather seems to point towards this form as being a progressive *Alcyonium*.

Burchardt's specimen was collected off Thursday Island.

Locality, etc.—"Pieter Faure," No. 12186. Durnford Point, N. 12 miles. Depth, 34 fathoms. Collected by dredge. Nature of bottom, broken shells. Date of collection, February 28, 1901.

Alcyonium (Erythropodium) reptans, Kük.

The specimen is very small and incomplete. The spicules and other features resemble Kükenthal's new species, but I am rather doubtful about this identification: his specimens were also collected at a much greater depth.

"Pieter Faure," No. 12070. O'Neil Peak, N.W. ¼ W. 9½ miles. Depth, 90 fathoms. Collected by dredge. Nature of bottom, broken shells. Date, February 28, 1901.

Alcyonium (Erythropodium) foliatum, sp. n.

The membranous, fairly thin base of the colony is growing over a sponge. The small polyps arise singly or are aggregated into masses. The calyces are low, and the anthocodiae retractile. The free polyps are sometimes almost in contact; at other times separated by a slight interval. The aggregated polyps are usually at about equal distances from one another. The basal part and calyces are white, the anthocodiae brown. When the anthocodiae are retracted, the calyces present an 8-rayed appearance. The diameter of the largest calyces is sometimes 2 mm. and the height ⅕ mm. The surface of the specimen, including the calyces, is densely covered with white spicules closely in contact with one another.

The size of the aggregated masses of polyps varies very considerably. One of the largest was 5 mm. in height and 4 mm. in diameter, and with about 36 polyps. Some of the larger polyps are 1·8 mm. in length and 1·5 mm. in diameter.

The spicules of the anthocodiae usually differ in form from those of the coenenchyme and calyces; they are disposed in 8 longitudinal stripes and a collarette at the base. In the collarette the spicules are about 6 in number at any one place, counting in a vertical direction. Spicules in the form of narrow spindles extend into the bases of the tentacles.

A vertical section through the aggregated masses of polyps shows that

the latter are very closely aggregated together with only narrow walls separating them, that the mesogloea is greatly reduced, and that the spicules extend far internally into the coenenchyme, forming a very efficient source of protection.

The spicules of the coenenchyme and calyces are double spheres, leafy clubs or spicules approaching leafy clubs, clubs and spicules approaching double wheels. The spicules of the anthocodiae are more predominantly clubs and spindles, although spicules resembling those of the coenenchyme and calyx also occur.

The following dimensions of the spicules may be noted:

From the coenenchyme and calyces: Double spheres from 0·045 × 0·024 to 1·11 × 0·072 mm.; leafy clubs from 0·057 × 0·03 to 0·108 × 0·045 mm.; clubs from 0·093 × 0·036 to 0·156 × 0·051 mm. From the anthocodiae: spindles from 0·057 × 0·012 to 0·126 × 0·012 mm.

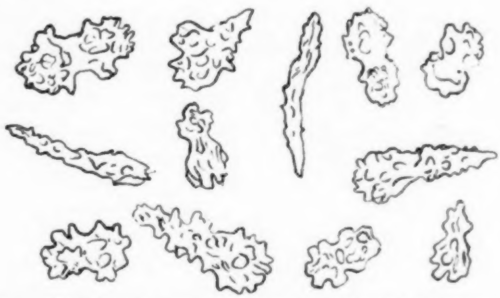


Fig. 2.—Spicules of *Alcyonium* (*Erythropodium*) *foliatum*, sp. n.

I have named this species *foliatum* from the shape of some of the spicules, which expand at one end in an almost leaf-like manner. Spicules slightly resembling these are found in *Alcyonium leptoclados*, Klunzinger, and *Alcyonium acaule*, Koch.

Locality, etc.—"Pieter Faure," No. 13364. Cape Morgan, N.W. ¼ W. 6½ miles. Depth, 45 fathoms. Collected by dredge. Nature of bottom, broken shells. Date of collection, August 13, 1901.

Alcyonium (Erythropodium) membranaceum, Kük.

This species has already been described and figured as a South African form by Kükenthal in his report on the Alcyonacea collected dnring the "Valdivia" Expedition. The locality was lat. 34° 7′ 3″ S., long. 24° 59′ 3″ E., St. Francis Bay; depth, 100 metres.

The localities in which it was collected by the "Pieter Faure" were:

"Pieter Faure," No. 287. Mossel Bay Lighthouse S. ¾ W. 2½ miles.

Depth, 10–12 fathoms. Collected by shrimp trawl. Date of collection, August 1, 1898.

"Pieter Faure" No. 291A. Cape St. Blaize, S. 70° W. 2½ miles. Depth, 12 fathoms. Collected by fish trawl. Date, August 2, 1898.

"Pieter Faure," No. 724. Lat. 33° 52′ 30″ S., long. 25° 50′ 33″ E. Depth, 25 fathoms. Collected by shrimp trawl. Nature of bottom, fine sand. Date, December 8, 1898.

ALCYONIUM (ERYTHROPODIUM) WILSONI, sp. n.

The specimen consists of broad band-like portions growing over a shell of the brachiopod *Kraussina rubra*, from which there rise at frequent intervals aggregations of polyps. These aggregations of polyps frequently have a superficial resemblance to small sea-anemones. Each aggregation usually consists of a basal column-like part, at the apex of which are the polyps. The polyp-cavities extend downwards through the column-like part. The polyp-cavities in the latter part are separated by fairly thick partition walls with spicules. The polyps are retractile, and in the retracted condition have the appearance of a central pit, around which are eight areas of spicules.

The column-like part has a fairly compact consistency, and is covered with white spicules. Numerous spicules of a similar colour protrude from the surface of the stolon. The spicules of the polyps cover the surface near the base and for some distance above, but nearer the apex they form a crown which is differentiated into eight areas. The bands of the stolons are sometimes 4 mm. in width and ⅛ mm. in thickness.

The aggregations of polyps vary very much in size, and in the numbers of polyps so aggregated together. In some such aggregations there may be 5 or 6, in others there may be 50 or 60. One of the largest of such aggregations is 9 mm. in length, 4 mm. in diameter and 3 mm. in height. In such polyp aggregations the polyps are close together with little space between them. The polyps are about 1·5 mm. in height and 1 mm. in diameter. The polyp cavities are continued down into wide canals, between which there is a fairly thick coenenchyme with many spicules and a few fine capillary tubes between the large cavities. Transverse sections remind one of the condition occurring in *Alcyonium*. The anthocodiae are short and there is little differentiation into parts; the only parts being a short basal part, the surface of which is covered with spicules, and a head on which the spicules are arranged in eight converging areas.

The spicules of the stolons are mainly spindles and clubs with broad processes, but there are other more irregular spicules, some quadrifid. The spicules from the outside of the short column-like parts, from which the aggregations of polyps arise, are on the whole similar to those of the stolon. The spicules on the outside of the polyp and from the coenenchyme are fairly similar.

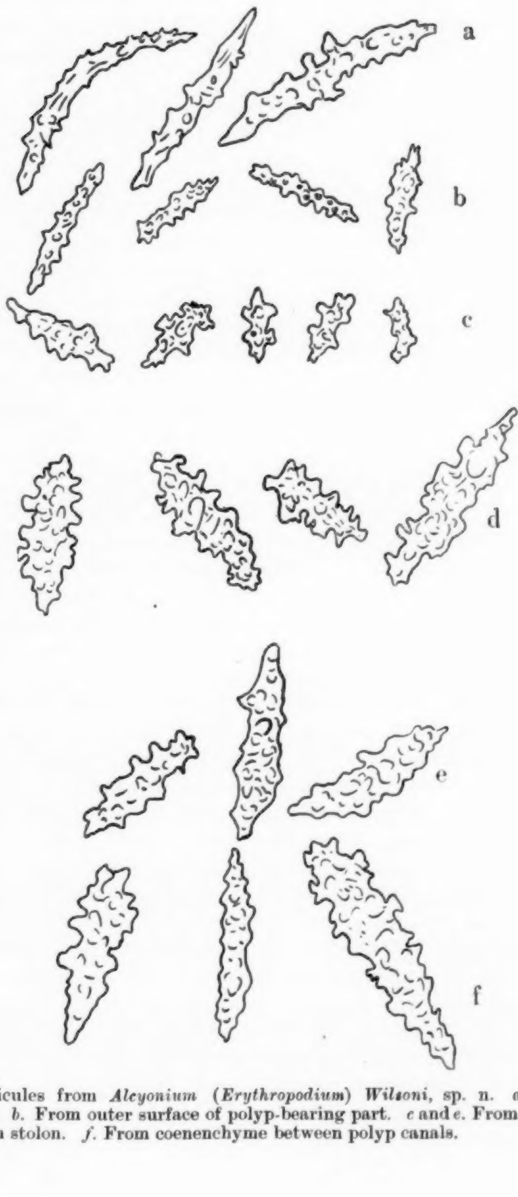


FIG. 3.—Spicules from *Alcyonium* (*Erythropodium*) *Wilsoni*, sp. n. *a*. From polyps. *b*. From outer surface of polyp-bearing part. *c* and *e*. From column. *d*. From stolon. *f*. From coenenchyme between polyp canals.

The size of the spicules is as follows: Narrow spindles from about 0·16 × 0·06 to 0·22 × 0·06 mm.; broader spindles from about 0·18 × 0·08 to 0·26 × 0·10 mm.; clubs from 0·08 × 0·04 to 0·35 × 0·10 mm.; irregular spicules from 0·10 × 0·06 to 0·10 × 0·12 mm.

Locality, etc.—"Pieter Faure," No. 10219. Knysna Heads, N.E. ¾ E. 3¼ miles. Depth, 40 fathoms. Collected by large dredge. Nature of bottom, sand, shell and coral. Date of collection, October 11, 1900.

Alcyonium (Metalcyonium) novarae, Kükenthal.

In the "Pieter Faure" Collection there are two specimens which show a number of points of resemblance with the species collected during the "Novara" Expedition at the Cape of Good Hope. Kükenthal has not given figures of this species, and as the two specimens in my collection are rather unsatisfactory, I am not completely sure of this identification.

Locality, etc.—"Pieter Faure," No. 5062. Rockland Point, N.W. ¼ N. 2½ miles. Depth, 23 fathoms. Collected by large dredge. Nature of bottom, rocks with many sponges. Date of collection, June 8, 1900.

Metalcyonium molle, Burchardt.

Five specimens, brownish in colour; the smallest 10 mm. in length and 4 mm. in diameter; the largest 28 mm. in length and 5–6 mm. in diameter; the stalk 21 mm. in length, expanded polyps at least 2 mm. long. The stalk fairly hard and tough, the hemispherical head soft. Spicules scanty, namely a few simple spindles in the cortex of the stalk, measuring 0·30 × 0·04 mm., and minute forms in eight areas beneath the tentacles and a few running in a circular direction, measuring 0·2 by 0·015 mm.

Metalcyonium molle, Burchardt, was collected in Australo-Malayan waters. It differs, however, from my specimens in being entirely without spicules, but on the other hand there are many other points of similarity. I have reviewed all the known species of *Metalcyonium* and *Nidalia*, and my specimens stand nearer *Metalcyonium molle* than to any other. It seems unnecessary to make this a new species.

Locality, etc.—"Pieter Faure," No. 10883. Umhloti River mouth, N. by W. ½ W. 8½ miles. Depth, 40 fathoms. Collected by large dredge. Nature of bottom, sand and shells. Date of collection, December 18, 1900.

"Pieter Faure," No. 10850 e. Same locality and depth. Two specimens with advanced ova in the gastral cavities.

Metalcyonium variabile, var molle, sp. n.

Syn. *Alcyonium antarcticum*, W. and S. (Hickson).

(Plate V, fig. 2; Plate VI, figs. 1–3.)

This form has already been described by Hickson from the Cape under the name *Alcyonium antarcticum*, W. and S., but this identification I regard

as incorrect. There has arisen some confusion about this species, and I may at once state that I do not hold this form, of which I have a number of examples, as being the same as that described as *Metalcyonium patagonicum* by May and Kükenthal. There is, however, no doubt that it is the same species as the form described by Hickson as *Alcyonium antarcticum*, W. and S.

The specimens vary very considerably in appearance according to the age and state of preservation. The following description applies to the finest specimen. It consists of a long stalk and a sub-globular head bearing very long polyps. The stalk is fairly hard in texture, the head much softer. The stalk is reddish; the head white, pink or yellowish. The former is fairly cylindrical, 23 mm. long and 5 mm. at its greatest diameter, namely, about the middle of its length; the latter is 10 mm. in length (without the polyps) and 15 mm. in diameter. The stalk and the head are well marked off from one another. On the head there are numerous well-developed polyps with young polyps between them. On the surface of the head there are numerous spicules between the polyps.

The polyps are translucent, and when well expanded are 14 mm. in length and 2 to 2·5 mm. in diameter. They are well protected by spicules, which are mainly long spindles. A calyx can scarcely be said to be present. When the polyp is contracted there is apparently a well-developed calyx, but this is merely due to the well-armed crown of the polyp being folded down and presenting an 8-rayed appearance.

The arrangement of the spicules of the polyps consists of (1) a few scattered spicules on the mesenterial filament part; (2) fairly numerous spicules partially arranged in 8 areas on the wall of the stomodaeal part, which are chiefly placed with their long axes parallel to the long axes of the polyps; (3) an apical crown of spicules in the form of inverted V's, each V with numerous spicules; (4) beneath these there is some trace of a circular band of transversely-placed spicules, but the direction in which these are disposed, whether transversely or longitudinally, appears to vary according to the degree of expansion of the polyps—in one case the circular ring had about 14 spicules placed transversely one below the other. The tentacles have spicules, but these are not arranged in two rows as they are in *Metalcyonium patagonicum*, May, but are more irregularly disposed. There are 12–16 pinnules on each side of the tentacles. On retraction of the polyps the tentacles are firstly withdrawn within the stomodaeal part; the lower part is then retracted and the apical crown projects on the surface of the head. Within the mesenterial filament part of the polyp mature ova were observed.

The spicules of the basal part of the polyp are short spindles, spinous rods, club and crosses; those of the stomodaeal part are longer spindles with slight processes. Towards the apex of the stomodaeal part the spicules are longer and almost needle-like. In the apical crown needle-like spicules

or long spindles predominate. The spicules from the surface of the head between the polyps are long spindles or shorter double spindles; those of the outer cortex of the stalk are double spindles, crosses, and more irregularly-shaped spindles. The spicules from the inside of the stalk are fairly similar to those of the cortex. The size of the spicules is as follows: (1) from the mesenterial filament part of the polyp, from $0{\cdot}12 \times 0{\cdot}02$ to $0{\cdot}34 \times 0{\cdot}035$ mm.; from the stomodaeal part, about $0{\cdot}10 \times 0{\cdot}015$ mm.; from the stomodaeal tube proper, about $0{\cdot}08 \times 0{\cdot}015$ mm.; from the apical crown, from $0{\cdot}105 \times 0{\cdot}03$ to $0{\cdot}52 \times 0{\cdot}03$ mm.; from the surface of the polyp head between the polyps, $0{\cdot}10 \times 0{\cdot}02$ mm.; from the outside of the stalk, from $0{\cdot}04 \times 0{\cdot}035$ to $0{\cdot}08 \times 0{\cdot}06$ mm.; from the inside of stalk, from $0{\cdot}07 \times 0{\cdot}024$ to $0{\cdot}10 \times 0{\cdot}06$ mm.; from the tentacles, from $0{\cdot}12 \times 0{\cdot}02$ mm.

Localities, etc.—"Pieter Faure," No. 15291. Knysna Head north, 10 miles. Depth, 52 fathoms. Collected by shrimp trawl. Nature of bottom, fine dark sand. Date, July 2, 1902.

"Pieter Faure," No. 10476. Cape St. Blaize, N. by E. 8½ miles. Depth, 39 fathoms. Collected by large dredge. Nature of bottom, stones. Date, October 22, 1900.

"Pieter Faure," No. 13245. Cove Rock, N. ¾ E. 5½ miles. Depth, 43 fathoms. Collected by dredge. Nature of bottom, stones and broken shells. Date, August 2, 1901.

"Pieter Faure, No. 655. S.S.W. of Cape Recife. Depth, 256 fathoms. Collected by dredge. Date, November 24, 1898.

"Pieter Faure," No. 2819B. Vasco da Gama, N. 71° E. 18½ miles. Depth, 230 fathoms. Collected by dredge. Nature of bottom, stones. Date, May 4, 1900.

"Pieter Faure," 795C. About 2½ miles S.E. off E. London. Collected by dredge. Depth, 32 fathoms. Nature of bottom, sand, shells and rocks. Date of collection, December 28, 1898.

"Pieter Faure," No. 14430. Cape Hangklip, N.E. ¾ N. 28½ miles. Depth, 100 fathoms. Collected by shrimp trawl. Nature of bottom, green sand. Date of collection, February 26, 1902.

This species differs from the form described by Kükenthal and May as *Metalcyonium patagonicum* in the following points: the occurrence of spicules in the lower part of the polyp; the presence of 14–16 pairs of pinnules instead of 10 pairs; the circular ring of spicules in the polyps is not prominent; the polyps are much larger, and the form of the specimen is not club-like.

From the specimens which I described in a previous paper as *Metalcyonium patagonicum*, May, this variety may usually be distinguished by the much harder and somewhat stony consistency of the outer surface of the stalk of the latter forms, while the stalk of *Metalcyonium variabilis* var. *molle* has in the preserved state a more leathery consistency.

Three large, white, mushroom-like specimens are relegated to this species, which at first sight seem far removed from it as regards their size, texture and general appearance. They afford very interesting examples of the extent to which an Alcyonarian species may vary. The arrangement and form of the spicules from the various parts of the colony are, however, similar. The dimensions of these specimens are as follows: Specimen A—Length, 71 mm.; length of stalk, 56 mm.; diameter of stalk, 21 mm.; head, 15 mm. in length by 32 mm. in diameter (without polyps). Specimen B—Length, 65 mm.; length of stalk, 49 mm.; diameter of stalk, 18 mm.; head, 16 mm. in length by 33 mm. in diameter; polyp, 9 mm. in length by 4 mm. in diameter at the apex. Specimen C—Length, 52 mm.; length of stalk, 46 mm.; diameter of stalk, 20 mm.; head, 6 mm. in length by 14 mm. in diameter.

At the base of this specimen there is an adult example of the Brachiopod *Terebratulina septentrionalis*, Couthouy, which Mr. J. W. Jackson, of the Manchester Museum, has kindly identified. It is probably a geographical variant of *Terebratulina caputserpentis*, Linné. The former species of Brachiopod was also dredged during the voyage of the "Challenger" off the Cape of Good Hope at a depth of 150 fathoms.

Locality, etc.—"Pieter Faure," No. 18171. Cape Point, N. by E. 9½ miles. Depth, 80–87 fathoms. Collected by trawl. Nature of bottom, green mud and sand. Date, October 28, 1903.

Metalcyonium variabile var. durum, sp. n.

Syn., *Metalcyonium patagonicum*, May (St. Thomson).

(Plate V, figs. 3, 4.)

The forms resembling *Metalcyonium variabile* var. *molle* to a large extent, but differing in the nature of the outer surface of the stalk and in other ways, I have now decided after much hesitation and consideration to call *Metalcyonium variabile* var. *durum*. I have a large number of these forms, and while if one takes extreme types of these two varieties there seems absolutely no difficulty in separating them even with the naked eye, one also has intermediate cases in which it is not easy to say in which variety the forms should be placed. As a rule, the outer surface of the stalk of such forms as I classify as *Metalcyonium variabile* var. *molle* contains spicules of predominantly one form, namely, double crosses, while that of those forms which I classify as *Metalcyonium variabile* var. *durum* shows greater variation in the form of the spicules. Thus one specimen "Pieter Faure," No. 655, shows, in addition to double crosses, longer spindles, rod-like spicules and small club-like forms; another specimen ("Pieter Faure," 13459) shows double crosses and transitions to double spheres, and specimen "Pieter Faure," 13135, shows a few double crosses

but predominantly double spheres. On the other hand, specimens from "Pieter Faure," 15291E, "Pieter Faure," 15291A, "Pieter Faure," 10476, "Pieter Faure," 795c, "Pieter Faure," 14430, which I regard as *M. variabilis* var. *molle*, have predominantly only double crosses. The two varieties may, however, occur in the same haul of a dredge (P. F. No. 655).

I have described the form *Metalcyonium variabile* var. *durum* fairly fully in a previous paper under the name *Metalcyonium patagonicum*, May, but it now appears to me that the occurrence of spicules in the stomodaeal tube, and other characters of the spicules and their arrangement, separate these forms from the species described by May. I have had the opportunity of examining the type "Challenger" specimen of *Alcyonium antarcticum* in the Natural History Museum, South Kensington, and Hickson's specimen from South Africa under that name does not agree with the "Challenger" form.

These specimens of *Metalcyonium variabile* appear to be extremely interesting as bearing out Prof. Hickson's contention as to the great variability of sedentary animals. Here we have a species which shows the greatest variation in colour, in shape, and in the form and arrangement of the spicules.

Localities, etc.—"Pieter Faure," No. 13125A. Cape Morgan, N.N.E. 9¾ miles. Depth, 47 fathoms. Collected by dredge. Nature of bottom, broken shells. Date, July 25, 1901.

"Pieter Faure," No. 655. S.S.W. of Cape Recife. Depth, 256 fathoms, Collected by dredge.

"Pieter Faure," No. 13459. Sandy Point, N.E. by N. 6½ miles. Depth, 51 fathoms. Collected by dredge. Nature of bottom, broken shells and stones.

"Pieter Faure," No. 13135. Cape Morgan, N.N.E. 9¾ miles. Depth, 47 fathoms. Collected by dredge. Nature of bottom, broken shells. Date, July 25, 1901.

"Pieter Faure," No. 2668. Vasco Da Gama, N.W. ¾ N. 8 miles. Depth, 41 fathoms. Collected by dredge. Nature of bottom, rocks. Date, April 27, 1900.

"Pieter Faure," No. 12108. O'Neil Peak, N.N.W. ¼ W. 8 miles. Depth, 55 fathoms. Collected by dredge. Nature of bottom, broken shells. Date, February 28, 1901.

"Pieter Faure," No. 13419. Mound Point, North 2½ miles. Depth, 34 fathoms. Collected by dredge. Nature of bottom, stones. Date, August 14, 1901.

"Pieter Faure," No. 13373. Cape Morgan, N.W. ¼ W. 6½ miles. Depth, 45 fathoms. Collected by dredge. Nature of bottom, broken shells. Date, August 13, 1901.

"Pieter Faure," No. 2668. Vasco da Gama, N.W. ¾ N. 8 miles. Depth,

41 fathoms. Collected by dredge. Nature of bottom, rocks. Date of collection, April 27, 1900.

METALCYONIUM LANCEATUM, sp. n.

One specimen only of this species is present in the collection, which has the following dimensions : Entire length, 73 mm. ; length of stalk, 36 mm. ; length of polyp-bearing part, 37 mm. ; basal diameter of stalk, 16 mm. ; basal diameter of polyp-bearing part, 15 mm. The stalk and the polyp-bearing part are not sharply marked off from one another, show little difference in consistency, and their surfaces are fairly hard. The polyp-bearing

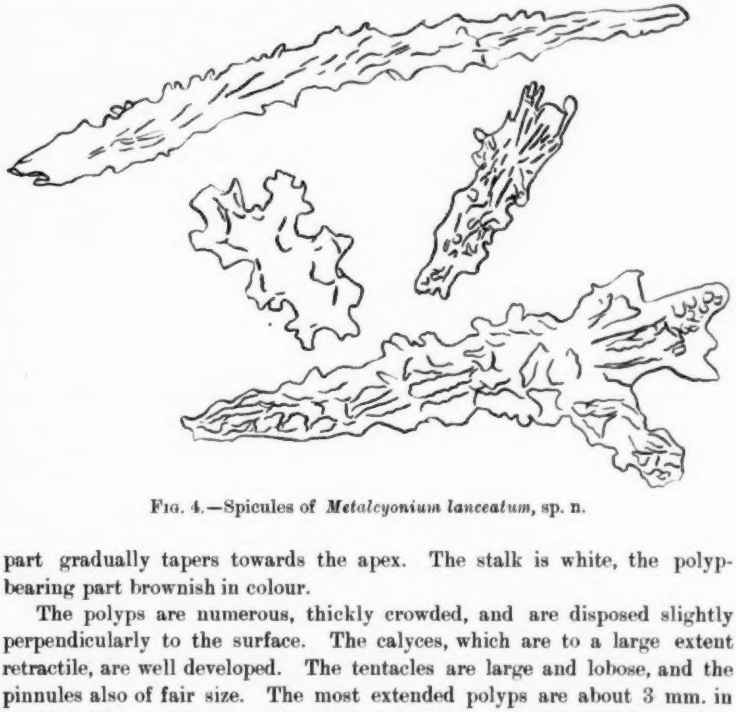


FIG. 4.—Spicules of *Metalcyonium lanceatum*, sp. n.

part gradually tapers towards the apex. The stalk is white, the polyp-bearing part brownish in colour.

The polyps are numerous, thickly crowded, and are disposed slightly perpendicularly to the surface. The calyces, which are to a large extent retractile, are well developed. The tentacles are large and lobose, and the pinnules also of fair size. The most extended polyps are about 3 mm. in length. They consist of a calyx, a short lower part without spicules, and an upper portion with the spicules arranged in eight inverted V-shaped areas. The calyx and the wall of the anthocodia are fairly similar in appearance. The gastral cavities of the polyps are continuous with canals which run down to the base. The gastral cavities of the polyps communicate indirectly with one another by a small network of canals—a point which has been

considered as of importance in distinguishing the genus *Metalcyonium*. Large ova are present in the gastral cavities. Large spicules are very thickly distributed in the superficial coenenchyme of the stalk and polyp-bearing part.

The spicules are mostly long, white spindles or rods with large processes on all sides, but there are also club-like forms. The spicules project in a marked manner from the surface, more especially from the calyx; they also form a very thick layer on the surface of the stalk.

The longer spindles and rods of the cortex of the stalk are about 2·08 mm. in length by 0·10 mm. in diameter, the shorter about 0·80 × 0·04 mm. The spicules of the tentacular part of the polyp are similar to the last in shape, but are smaller, such as 0·4 × 0·3 mm. The spicules of the calyces and of the coenenchyme between the polyps are fairly similar to those in the outer part of the stalk. The spicules from the interior of the polyp-bearing part are also fairly similar; some are 0·80 × 0·10 mm. These spicules are so long and fragile that they are very apt to become broken while being mounted. Spicules are more abundant in the interior of the stalk than in that of the polyp-bearing part; some of the former are as much as 2·3 mm. in length, and I have named the species from these long lance-like spicules placed longitudinally or obliquely, more especially in the interior of the stalk.

Many points in this specimen are similar to those of *Sinularia unilobata*, but the arming of the polyps with spicules is conspicuously different. It is apparently a species of *Metalcyonium* according to Kükenthal's diagnosis of this genus. It shows some affinities with *Metalcyonium clavatum*, Pfeffer, but differs from it in the arrangement of the spicules and in other points.

Locality, etc.—"Pieter Faure," No. 13626. Great Fish Point Lighthouse, W. by N. 5 miles. Depth, 22 fathoms. Collected by dredge. Nature of bottom, rocks, hard polyzoa and corals. Date of collection, August 29, 1901.

SARCOPHYTUM TROCHIFORME, Hickson.

Syn., *Anthomastus trochiforme*, Kükenthal.

Localities, etc.—"Pieter Faure," No. 11524. Tugela River mouth, N.W. 20 miles. Depth, 37 fathoms. Collected by large dredge. Nature of bottom, sand and shells. Date, January 29, 1901.

Two specimens from the locality given above, one red, the other orange-yellow in colour. Autozooids in both specimens retracted, about 1·5 mm. in diameter. Siphonozooids 0·25 to 0·5 mm. in diameter.

"Pieter Faure," No. 11128. Umkomaas River mouth, N.W. by W. ½ W., 5¼ miles. Depth, 40 fathoms. Collected by large dredge. Nature of

bottom, broken shells and stones. Date of collection, December 31, 1900. A red specimen.

"Pieter Faure," No. 10993. Off Umhloti River mouth. Depth, 39–40 fathoms. Collected by large dredge. Nature of bottom, sand and shells. Date of collection, December 21, 1900. Five specimens, four brownish red and one yellowish white.

"Pieter Faure," No. 10992. Same locality as last. One small brownish-red specimen.

"Pieter Faure," No. 12483. Red-topped hill, west of Umtwalumi, N. by W. 2 miles. Depth, 25 fathoms. Collected by dredge. Nature of bottom, broken shells. Date of collection, March 22, 1901. A reddish specimen.

"Pieter Faure," No. 12059. O'Neil Peak, N.W. ¼ W., 9½ miles. Depth, 90 fathoms. Collected by dredge. Nature of bottom, broken shells. Date of collection, February 28, 1901. One young specimen, the stalk wound round the axis of a foreign body.

ANTHOMASTUS GRANULOSUS, Kük.

The specimen is 1·5 cm. in length, the stalk 2 mm. in diameter, the head 2 mm. in height and 4 mm. in diameter. The ground-colour of the colony is light red, and the calyces are orange yellow. I have no doubt that this specimen is a young form of the species described and figured by Kükenthal from Japanese seas under the name *Anthomastus granulosus*. The size and the shape of the spicules are essentially similar. Kükenthal emphasises two points regarding this species—firstly, that it is the only species of this genus in which longer, rod-like spicules are absent, and secondly, the only one in which double spheres are present.

The Japanese specimens were collected at Tokio and Enoura Bays at depths of 20 and 200 metres respectively.

The South African specimen was collected as follows: "Pieter Faure," No. 799. About 2¼ miles S.E. of East London. Depth, 32 fathoms. Collected by dredge. Nature of bottom, sand, shells and rocks. Date, December 28, 1898.

ANTHOMASTUS ELEGANS, Kükenthal.

The specimen agrees in essential points with that described by Kükenthal, differing only in minor details such as the colour, the height and the form of the stalk. The species was first collected during the voyage of the "Valdivia" in the southern part of the Agulhas Bank (lat. 35° 19′ S., long. 20° 12′ E.).

My specimen was collected as follows: "Pieter Faure," No. 12073. O'Neil Peak, N.W. ¼ W. 9½ miles. Depth, 90 fathoms. Collected by dredge. Nature of bottom, broken shells, etc. Date of collection, February 28, 1901.

"Pieter Faure," No. 10880. Umhloti River mouth, N. by W. ½ W. 8½ miles. Depth, 40 fathoms. Collected by large dredge. Nature of bottom, sand and shells (hard ground). Date, December 18, 1900.

Acrophytum claviger, Hickson.

Syn., *Metalcyonium natalense*, St. Thomson.

In 1910 I described a specimen from off Umhloti River mouth (Natal) as *Metalcyonium natalense*. The advantage of having a large number of specimens for comparison has shown itself, as I am now enabled to place these as identical with the form described by Hickson as *Acrophytum claviger*. In 1910 I failed to recognise the presence of siphonozooids, regarding the smaller zooids as only young autozooids, and this mistake is understood in the light of Hickson's statement that "it is impossible to distinguish except in a series of sections the young retracted autozooids from siphonozooids."

The various specimens of this species are interesting in showing (1) the differences between expanded and contracted examples, (2) the varied relative lengths of the basal and upper parts of the colony (in one specimen the zooids extend far towards the base), (3) the varied shape of the upper part of the colony, sometimes club-like, at other times almost spherical.

It is clear that this species, especially in the preserved state, may vary very much in external characters, but that the character and arrangement of the predominantly club-shaped spicules is unmistakable. My specimens agree in the main with the description of this genus and species given by Hickson, differing mainly in the occurrence of zooids towards the base of the colony, and that Hickson does not mention the presence of a few rods or simple spindles in the interior of the coenenchyme. The specimens were procured at the following localities:

"Pieter Faure," No. 10994. Off Umhloti River mouth. Depth, 39 to 40 fathoms. Nature of bottom, sand and shells. Collected by large dredge. Date of collection, December 21, 1900.

"Pieter Faure," No. 12322. Port Shepstone, N. 8 miles. Depth, 36 fathoms. Collected by large dredge. Nature of bottom, broken shells and stones. Date of collection, March 14, 1901.

"Pieter Faure," Nos. 12475 and 12478. Red-topped hill, west of Umtwalumi Rocks N. by W. 2 miles. Depth, 25 fathoms. Collected by dredge. Nature of bottom, broken shells, etc. Date of collection, March 22, 1901.

"Pieter Faure," No. 12168. Durnford Point, N.W. by N. 11 miles. Depth, 45 fathoms. Collected by dredge. Nature of bottom, shells and stones. Date of collection, February 28, 1901.

"Pieter Faure," No. 11845. Durnford Point, N.E. by E. 9 miles. Depth,

13 fathoms. Collected by dredge. Nature of bottom, sand and shells. Date of collection, February 8, 1901.

"Pieter Faure," No. 13375. Cape Morgan, N.W. ¾ W. 6½ miles. Depth, 45 fathoms. Collected by large dredge. Nature of bottom, broken shells. Date of collection, August 13, 1901.

"Pieter Faure," No. 10862. Umhloti River mouth, N. by W. ½ W. 8½ miles. Depth, 40 fathoms. Collected by large dredge. Nature of bottom, sand and shells (hard ground). Date of collection, December 1, 1900.

Bellonella Studeri, St. Thomson.

In 1910 I described this species from South African seas. The present specimens have the following dimensions: Specimen A, length 44 mm.; polyp-bearing part, 28 mm. in length by 7 mm. in diameter; stalk, 16 mm. in length by 9·5 mm. in diameter: Specimen B, length 40 mm., polyp-bearing part, 24 mm. in length by 17 mm. in diameter; stalk, 16 mm. in length by 13 mm. in diameter.

Localites.—"Pieter Faure," No. 12479. Red-topped hill west of Umtwalumi River, N. by W. 2 miles. Depth, 25 fathoms. Collected by dredge. Nature of bottom, broken shells. Date of collection, March 22, 1901.

"Pieter Faure," No. 13836. Glendower Beacon, N. ½ W. 16½ miles. Depth, 66 fathoms. Collected by dredge. Nature of bottom, broken shells and stones. Date of collection, September 10, 1901.

Malacacanthus rufus, St. Thomson.

(Plate V, fig. 5.)

This is an interesting form but not new to me. The present specimen throws a light on the form "Pieter Faure," 15888, which I described in my first paper on Cape Alcyonacea—a form without spicules. It is permeated without and within by foreign bodies, such as grains of sand, shells of Foraminifera, sponge spicules, etc. The specimen evidently lives in sand, and the absence of spicules may be compensated for by the incorporation of numerous foreign bodies. It is possible that mucus-secreting cells are present which may entangle the foreign particles after the manner of those which form the tube around the body of the Sea anemone, *Cerianthus*. On finding my first specimen of this species I had some doubt about this form really being devoid of spicules, but the present specimen was examined externally and internally, and the supposed absence of spicules has been confirmed. The specimen has a harder consistency than the one which I previously described.

Locality, etc.—"Pieter Faure," No. 13960. Great Fish Point Light-

house, N.W. 9 miles. Depth, 51 fathoms. Nature of bottom, sand and shells. Date of collection, September 3, 1901.

"Pieter Faure," No. 2668. Vasco da Gama N.W. ¾ N. 8 miles. Depth, 41 fathoms. Collected by dredge. Nature of bottom, rocks. Date, April 27, 1900. (This specimen was in an unsatisfactory condition for identification as the contents of the bottle had become dried during transit.)

Sinularia (Sclerophytum) unilobata, sp. n.

Chief characteristics.—Specimen almost cylindrical, resembling *Metalcyonium* and *Nidalia* in general form. Texture of colony extremely hard. Polyp-bearing part not divided up into lobes. Polyps large, 2–4 mm. in length, 2 mm. in diameter at base when contracted, 2·5 mm. in diameter across the crown of tentacles. Tentacles broad and blunt, about 7 mm. in length; pinnules, a double row down each side of the tentacles. Siphonozooids not present. Mesenteries well marked, ventral mesenterial filaments fairly long. Reproductive organs not observed. Superficial and internal canal systems well marked, and canals numerous. Zoochlorellæ not numerous. Spicules of polyp-bearing part numerous near the surface, mostly clubs with tubercles slightly arranged in zones, few spicules in the interior of the same part, and mostly very long and narrow spindles or rods. Spicules of the external stalk, large clubs or spindles resembling those on the surface of the polyp-bearing part. Branched spicules, such as in those figured by Pratt in various species of *Sclerophytum*, not present in this form. No spicules in the anthocodiae of the polyps.

Notes on specimens.—The largest specimen is curved and cylindrical in shape. The polyp-bearing part is fairly sharply marked off from the stalk; the former is considerably longer than the latter. The polyps are large, numerous, and almost in contact at the bases, and are capable of almost complete retraction. The polyp is differentiated into three parts, namely, a crown of green tentacles, a stomodaeal part, and a cup-like part raised above the general surface of the superficial coenenchyme, and protected externally by large white, club-shaped spicules. The tentacles and pinnules are rather plump. In the retracted condition, a striking feature is the width of the wall of the cup-like basal part of the polyp. The size and massive condition of the spicules projecting on the external surface of the coenenchyme of the polyp-bearing part is noteworthy. The spicules of the stalk are densely crowded together, and the latter expands slightly in a horizontal or lateral direction at the base.

The following dimensions may be noticed: stalk about 36 mm. in length and 13 mm. in diameter; polyp-bearing part about 38 mm. in length and 15 mm. in diameter near the base and 9 mm. near the apex; diameter of cup-like basal part of polyp, sometimes 1·75 mm.; largest polyps, 4 mm.

in length from apex to extreme base. The spicules may be distinguished into club-like and more cylindrical forms. A striking feature of the polyp-bearing part is the manner in which the massive spicules project almost vertically upward at the bases of the polyps. The spicules of the polyp-bearing part are large clubs, and more cylindrical rod-like and spindle-like forms. There are few spicules in the interior either of the polyp-bearing part or of the stalk. The clubs of the polyp-bearing part are varied in size: some are from 0·24 × 0·12 to 0·98 × 0·28 mm., the more cylindrical spicules from 0·30 × 0·07 to 0·80 × 0·10 mm. In the external coenenchyme of the stalk clubs also occur, but they are rarer, the common type being more cylindrical. The clubs may measure from 0·30 × 0·12 to 0·58 × 0·38 mm., the more cylindrical forms from 0·28 × 0·10 to 0·86 × 0·2 mm.; a few

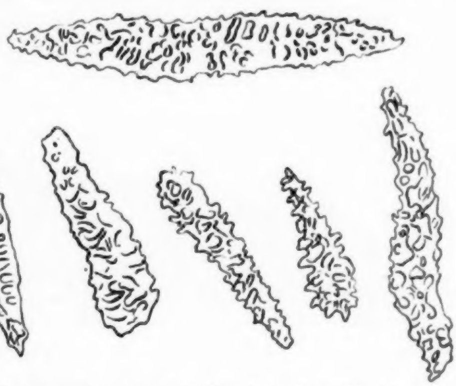


FIG. 5.—Spicules of *Sinularia* (*Sclerophytum*) *unilobata*, sp. n.

exceptionally large spicules are 1·40 mm. in length by 0·22 mm. in diameter. A striking feature of the spicular arrangement of the stalk is the occurrence of very large spicules lying as a rule slightly internal to the smaller forms. The spicules of this species attain a large size. The following dimensions in millimetres of ten large spicules taken at random from the external part of the base of another specimen may be noted: 1·36 × 0·32; 1·40 × 0·28; 1·40 × 0·32; 1·50 × 0·52; 1·60 × 0·34; 1·76 × 0·40; 1·94 × 0·30; 2·20 × 0·38; 0·222 × 0·034; 2·60 × 0·04.

I must here express my agreement with Cohn and Kükenthal in the view that the genus *Sclerophytum* is identical with the genus *Sinularia*, and the latter name has priority. The present example of the genus *Sinularia* also shows certain resemblances with the genus *Sarcophytum*. There is apparently a fairly close relationship between the three genera, *Sarcophytum*, *Lobophytum*, and *Sinularia*.

Localities, etc.—"Pieter Faure," No. 12482. Red-topped hill west of Umtwalumi, N. by W. 2 miles. Depth, 25 fathoms. Collected by dredge. Nature of bottom, broken shells.

"Pieter Faure," No. 13461. Sandy Point, N.E. by N. 6½ miles. Depth, 51 fathoms. Collected by dredge. Nature of bottom, broken shells and stones. Date of collection, August 14, 1901.

"Pieter Faure," Nos. 10862 and 10867. Umhloti River mouth, N. by W. ½ W. 8½ miles. Depth, 40 fathoms. Collected by large dredge. Nature of bottom, sand and shells. Date of collection, December 18, 1900.

"Pieter Faure," Nos. 13054 and 13054B. Hood Point Lighthouse, N. by W. ½ W. 11¼ miles. Depth, 49 fathoms. Collected by dredge. Nature of bottom, broken shells. Date of collection, July 15, 1901.

"Pieter Faure," No. 10880. Umhloti River mouth, N. by W. ½ W. 8½ miles. Depth, 40 fathoms. Collected by large dredge. Nature of bottom, sand and shells. Date of collection, December 18, 1900.

"Pieter Faure," No. 852½. About 25 miles east of East London. Lat. 32° 48′ 30″ S.; long. 28° 11′ 15″ E. Depth, 22 fathoms. Collected by shrimp trawl. Nature of bottom, mud. Date of collection, January 11, 1899.

From "Pieter Faure," 795C. About 2¼ miles S.E. of East London. Depth, 32 fathoms. Collected by dredge. Nature of bottom,, sand, shells and rocks. Date of collection, December 28, 1898.

In conclusion, I would express my indebtedness to Miss A. Dixon, of Manchester University, who saved me much time and drudgery by making a number of preparations of spicules, and to Prof. S. J. Hickson, F.R.S., who lent me some of the literature. In regard to the literature, in order to reduce the letterpress I have not added a bibliography of all the papers consulted, but reference may be made to the list at the end of Prof. Kükenthal's memoir on the Alcyonacea collected during the "Valdiva" Expedition, and to the following papers dealing more especially with South African Alcyonacea:

Hickson, S. J. (1900). 'The Alcyonaria and Hydrocorallinae of the Cape of Good Hope,' Part I, "Marine Investigations in South Africa," vol. i, No. 5 (Cape Town, 1904).

Hickson, S. J. (1904). 'The Alcyonaria of the Cape of Good Hope,' Part II, "Marine Investigations in South Africa," vol. iii (Cape Town).

Thomson, J. Stuart (1910). "The Alcyonaria of the Cape of Good Hope and Natal: Alcyonacea," 'Trans. Roy. Soc. Edin.,' vol. xlvii, pt. 3, No. 19.

EXPLANATION OF THE PLATES.

PLATE V.

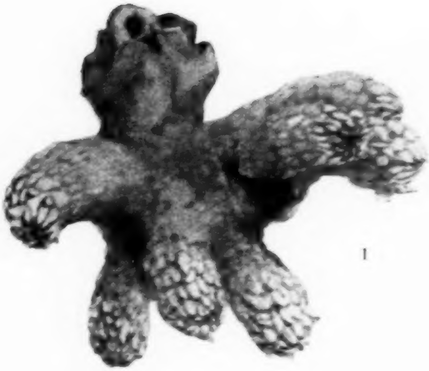
FIG.
1. ***Scleranthelia musiva*,** Studer. × 3·5.
2. ***Metalcyonium variabile*,** var. *molle*. × 1¼.

3, 4. ***Metalcyonium variabile*,** var. *durum*, n. sp. et n. var. × 2.

5. ***Malacacanthus rufus*,** St. Thomson. Nat. size.
6. ***Alcyonium pachyclados*,** Klunzinger. Nat. size.
7. ***Alcyonium pachyclados*,** Klunzinger, contracted polyps. × 8.
8. ***Alcyonium pachyclados*,** Klunzinger, expanded polyps. × 10.

PLATE VI.

1–3. ***Metalcyonium variabile*** var. *molle*, n. sp. et n. var. Nat. size.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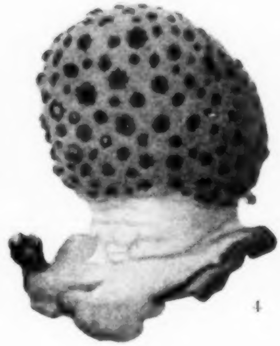
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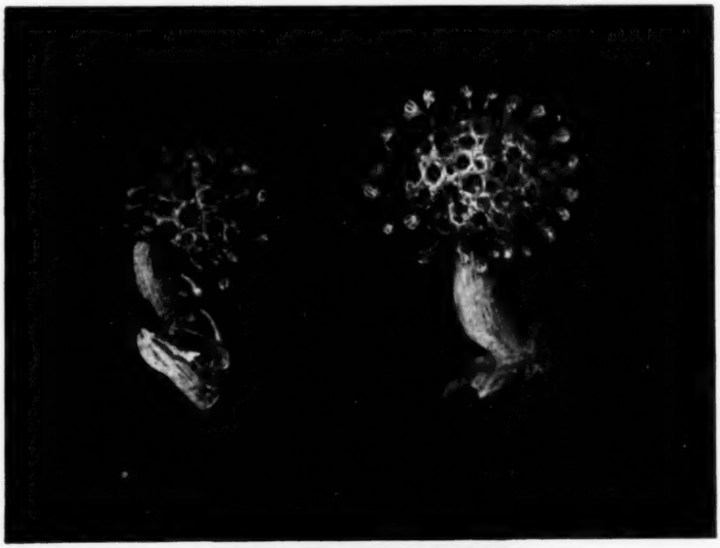

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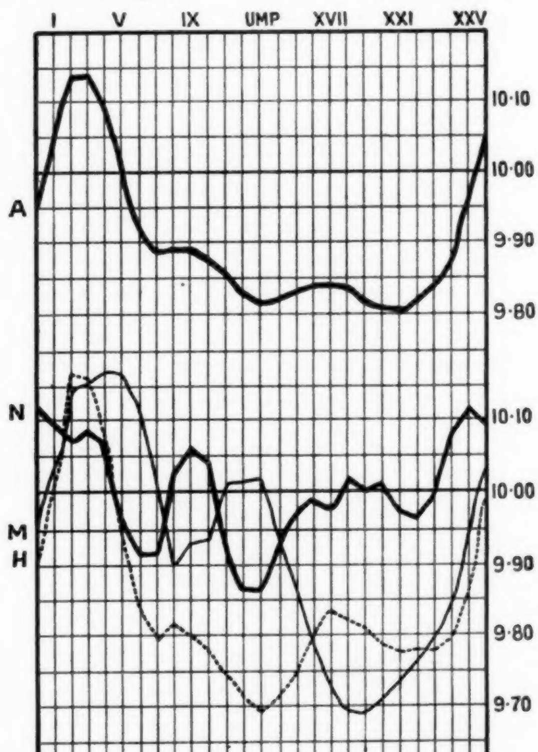
A POSSIBLE LUNAR INFLUENCE UPON THE VELOCITY OF THE WIND AT KIMBERLEY.

(Third Paper.)

By J. R. Sutton.

(With one Text-figure.)

The present paper deals with the variations in the velocity of the wind when the moon is near apogee. The observation period extends from April,



Velocity Variation Curves.
A. Apogee curve. N. "Noon" apogee curve. M. "Midnight" apogee curve. H. "Horizon" apogee curve.

1897, to December, 1919, comprising 298 apogees. The method followed is the same as that of the previous paper, departures from the hourly means being arranged in hours of the lunar day. This is no doubt a better way of dealing with the matter (though a much more laborious one) than that of merely tabulating the velocities themselves, even though it may not be so necessary as in the case of perigee, seeing that the moon's culminations at apogee are fairly evenly distributed over the hours of the solar day. The observations made use of are those for the day of apogee together with those of the day before and the day after, 894 days in all.

Wind Velocity Variation at Apogee in Miles an Hour.

Hour.	Mean apogee.	"Noon" apogee.	"Midnight" apogee.	"Horizon" apogee.
L.M.P	10·054	10·093	10·036	10·045
II	10·140	10·071	10·146	10·167
III	10·140	10·080	10·151	10·160
IV	10·093	10·069	10·167	10·067
V	10·002	9·957	10·164	9·945
VI	9·925	9·912	10·111	9·841
VII	9·881	9·923	10·016	9·797
VIII	9·882	10·025	9·900	9·810
IX	9·890	10·053	9·929	9·799
X	9·876	10·037	9·936	9·776
XI	9·854	9·926	10·015	9·744
XII	9·825	9·862	10·017	9·715
U.M.P	9·814	9·863	10·019	9·694
XIV	9·823	9·935	9·952	9·712
XV	9·828	9·973	9·860	9·750
XVI	9·839	9·986	9·778	9·804
XVII	9·839	9·980	9·727	9·831
XVIII	9·832	10·014	9·694	9·818
XIX	9·821	9·998	9·692	9·805
XX	9·817	10·007	9·707	9·786
XXI	9·808	9·976	9·731	9·771
XXII	9·817	9·969	9·762	9·777
XXIII	9·829	9·989	9·791	9·777
XXIV	9·869	10·084	9·832	9·792
L.M.P	9·964	10·114	9·929	9·915
Mean	9·899	9·996	9·922	9·844
Range	0·332	0·252	0·475	0·473
No.	894	204	225	465

In the above table column 1 indicates the hours of the lunar day.

Column 2 gives the hourly means of the deviations $V—v + 10$ for all the 894 days.

Column 3 gives the means of the deviations when the moon near apogee culminates between IX and XV.

Column 4 the same for culminations between XXI and III.

Column 5 the same for the remaining hours.

These "noon" and "midnight" culminations have been extended over a six-hour range, instead of over the four-hour range (X to XIV, and XXII to II) used for perigee terms, in order to give a larger number of observations for discussion, and so smoother curves, for those culminations. But of course such an extension of the time limits must impart something of the "horizon" character to the "noon" and "midnight" curves deduced.

As before, all the tabular numbers have been smoothed in threes.

The curves shown in the diagram are best studied by comparison with the perigee curves of the second paper. Generally they show the same turning-points as the perigee curves, but somewhat lagging, and the moonrise minimum is not so pronounced, *e. g.*:

"*Noon*" *Curves.*

Maxima:	Perigee	XXII	XI	XVI
	Apogee	L.M.P	IX	XVIII
Minima:	Perigee	IV	XII	XX
	Apogee	VI	XII	XXII

"*Midnight*" *Curves.*

Maxima:	Perigee	L.M.P	X	XX
	Apogee	IV	U.M.P	
Minima:	Perigee	VI	XVI	
	Apogee	VIII	XIX	

"*Horizon*" *Curves.*

Maxima:	Perigee	II	VIII	XIV
	Apogee	II	VIII	XVII
Minima:	Perigee	VI	XI	XX
	Apogee	VIII	U.M.P	XXI

Mean Curves.

Maxima:	Perigee	XXIV	IX	XVI
	Apogee	II	IX	XVII
Minima:	Perigee	VI	XII	XIX
	Apogee	VII	U.M.P	XXI

It is an interesting fact that all the apogee curves average lower on the

scale than the corresponding perigee ones do, mean values in miles an hour being—

	Perigee.	Apogee.	Difference P.—A.
"Noon"	10·132	9·996	·136
"Midnight"	10·036	9·922	·114
"Horizon"	9·882	9·844	·038
Mean	9·994	9·899	·095

Further, while the velocity tends to rise when the moon is above the horizon at perigee, it tends to fall at apogee. And while the perigee curves end the lunar day at a higher level than they started at, the apogee curves run down. The relatively large range of variation shown by the apogee curve is probably due to this circumstance.

In their general tendency the results so far obtained are pretty much what might have been expected; but the actual ranges of velocity are greater than I looked for, reasoning from the thermodynamical analogy of the semi-diurnal oscillation of barometric pressure. Their acceptance would demand for the purely dynamical problem of the air tide a lively circulation throughout the whole depth of atmosphere. On the negative side of the account it may be claimed that at the least if, at a place so favourably situated as Kimberley is for a research of this kind, the moon at its best cannot create a range of wind velocity of more than 0·7 mile an hour in the course of a whole day, then how can it possibly promote the storm and tempest attributed to it by the weather prophets?

Again I have to thank my wife for her assistance.

SOUTH AFRICAN XYLARIAS OCCURRING AROUND DURBAN, NATAL.

By Paul A. Van der Bijl.

(With Plates VII and VIII.)

The genus *Xylaria* belongs to the *Pyrenomycetes* group of the *Ascomycetes* fungi and is included in the family *Xylariaceae*.

The members of this family are characterised by their superficial stromata, with the perithecia arranged along the periphery of the stromata and usually embedded in them, though at times more or less protruding. They have brown to dark-coloured usually 1-celled spores borne in cylindrical asci.

From other members of the family the genus *Xylaria* is distinguished by the following combined characters: (1) Stroma black, erect, branched or unbranched, globose, cylindrical or club-shaped, *and with a shorter or longer sterile stalk* which is rarely obsolete; (2) perithecia *many*, along the periphery of and embedded in the stroma or more or less protruding and rarely partly free; (3) asci cylindrical; spores brown or dark-coloured, ovoid, 1-celled, straight to slightly fusoid.

In the young stage the fertile portion or club of the stroma is covered with a whitish, felt-like conidial layer. Specimens in this stage are immature and cannot be specifically determined.

The genus *Xylaria* can for convenience be divided into two main divisions *: (1) those with solid stromata, (2) those with the centre of the stromata pithy and becoming hollow. All the species herein dealt with belong to the first division.

Xylaria spp. are most frequently found growing saprophytically either in the ground or on decaying wood, fruit, etc. It is, however, interesting to note that Fomme and Thomas† and subsequently Wolf and Cromwell‡ have associated *Xylaria* spp. with a root-rot of apple trees. In 1912 the writer, on a visit to Mr. de Villiers, dist. Ermelo, Transvaal, observed invariably among the roots of dying carnation plants a rich growth of a

* Lloyd, C. G., 'Xylaria Notes,' No. 1, 1918.

† Fomme, F. D., and Thomas, H. E., "The Root Disease of the Apple in Virginia," 'Science,' n.s., xlv, 1917.

‡ Wolf, F. A., and Cromwell, R. O., "Xylaria Root-rots of Apple," 'Journ. Agric. Res.,' ix, p. 269, 1917.

Xylaria sp.*. The fungus could not actually be traced in contact with the roots, and at the time it was thought that the fungus grew primarily in the rich kraal manure with which the plants had been treated and caused the death of the plants by smothering the root system.

Though the *Xylarias* are quite conspicuous objects on the substrata on which they grow, but little is known of the South African species. Four species have thus far been collected by the writer around Durban, and of these three have not been previously recorded from South Africa. We give the undermentioned key of the species occurring around Durban and follow it with brief descriptions of each species.

Key to Xylaria spp. occurring around Durban.

1. Plants growing only on fallen and decaying fruits . . . 1. *X. multiplex.*
1. Plants not of above habitat.
  2. Surface of clubs with fine raised lines and apex usually prolonged into a distinct apiculum . . . . 2. *X. apiculata.*
  2. Surface of clubs not as above and apex not prolonged into an apiculum.
    3. Surface of clubs moriform through protruding perithecia. 3. *X. anisopleura.*
    3. Surface rugulose.
      4. Spores 20–30 × 7–11. . . . . 4. *X. polymorpha.*

Descriptions of the Species.

1. Xylaria multiplex (Kze.) Fries. (Figs. 1 and 2.)

Plants growing on various fruits, solid, black without, white within; clubs slender, cylindrical to compressed, subdivided; surface strongly moriform with the protruding perithecia and especially so the slender branches; stalk densely villous with dark hairs; perithecia globose; asci cylindrical, 8-spored; spores brown to dark, ovoid, straight to slightly fusoid, older uniguttulate, 7–11 × 4 μ.

Common on fallen fruits of *Strychnos Gerrardi*. This fungus appears to always grow on fruits, and Lloyd records it from tropical America as particularly growing on large pods of Leguminoseae. *Its habitat should aid in recognition.* My collection is the first record of the plant from South Africa.

2. Xylaria apiculata, Cke. (Fig. 3.)

Plants epixylous, solid, black without, white within; clubs cylindrical, 5–1·5 cm. long × 2 mm. across, single or 2–4 on the same stalk, *usually with a prominent apical apiculum*; *surface striate with fine raised lines*; stalks

* van der Bijl, P. A., "The Nature of Fungi, with Reference to the Life-histories of some Important Parasites," 'Agric. Journ. Union S. Africa,' vi, p. 904, 1913.

·1–1·5 cm. long × 1 mm. diam., villous with dark hairs; perithecia globose, not protruding, 130–200 μ diam.; asci cylindrical; spores brown to dark, straight to slightly fusoid, 11–15 × 4–6 μ; when young with a large gutta, when old often with an indistinct septum.

On dead and decaying logs. This plant was described by Cooke from New Zealand. It also occurs in Madagascar and the American tropics and my collection is the first record from South Africa. *The raised lines on the clubs are peculiar and should aid in recognition.*

3. Xylaria anisopleura, Mont. (Fig. 4.)

Plants epixylous, solid, black without, white within; clubs solitary or fasciculate, 1–2·5 cm., globular to oval, at times compressed, branched, and more or less lobed; *surface moriform with protruding perithecia*; stalks ·5–1 mm. long, often rudimentary, villous at base; perithecia globose, up to 780 μ diam.; spores brown to dark, ovoid, straight to slightly fusoid, uniguttulate, 22–30 × 7–9 μ.

On dead and decaying wood. Distinguished from *X. polymorpha* by moriform surface.

4. Xylaria polymorpha (Pers.), Grev. (Fig. 5.)

Plants epixylous; clubs various, rarely solitary, more often fasciculate or tufted, 2–7-connate at base, simple or palmately branched, sometimes terete or globose, more often compressed, solid, black without, white within; *surface rugulose*; stipe ·7–2 cm. long × 2–5 mm. diam., at times obsolete; perithecia ovate, slightly protruding; spores brown to dark, ovoid, straight to fusoid, 20–30 × 7–11 μ.

On rotting wood. Distinguished from *X. anisopleura* by rugulose surface and usually broader spores. The name "polymorpha" refers to the many and varied forms this fungus takes.

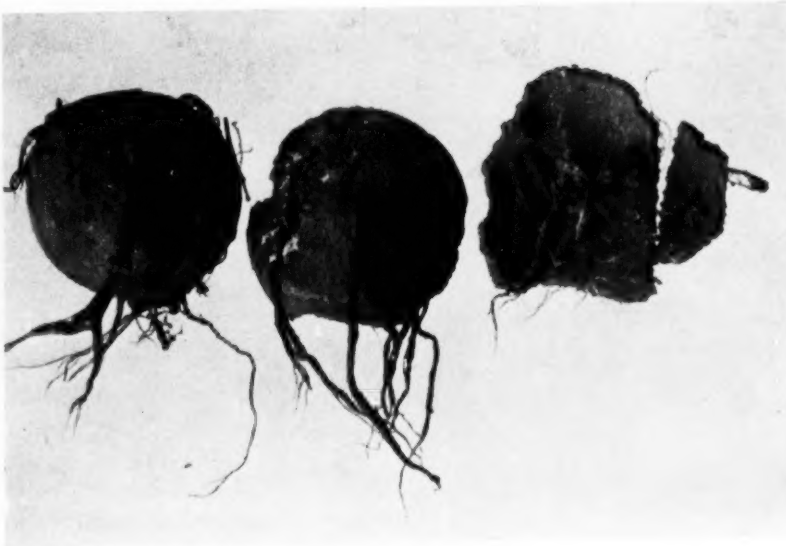


Fig. 1.

Fig. 2.

Fig. 3.

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FIG. 4.

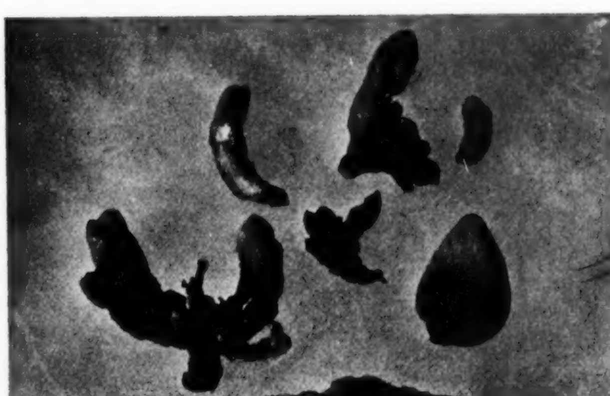

FIG. 5.

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THE GENUS TULOSTOMA* IN SOUTH AFRICA.

By Paul A. van der Bijl.

(With Plate IX).

The genus *Tulostoma* belongs to the family *Lycoperdaceae*, a family familiar to most through the "puff-balls" included in it. It is a widely-distributed genus, and in South Africa two species are thus far known, viz. *Tulostoma cyclophorum*, Lloyd, and *Tulostoma Lesliei*, n. sp., herein described. Massee† records *Tulostoma mammosum* (Mich.), Pers., from South Africa, but this species appears to belong typically to Europe and England, and has not been collected in Africa during recent years.

The genus is with others included in the tribe *Tulostomeae*,‡ which embraces those *Lycoperdaceae* which have peridia borne on a distinct stalk *not confluent with the peridia* (distinguish some *Sclerodermeae* and some *Lycoperdeae*) and *not prolonged as an axis into the peridia* (distinguish *Podaxineae*). From other genera of this tribe the genus *Tulostoma* is recognised by the following two characters: (1) *the stalk is inserted into a depression at the base of the peridium*; (2) *the peridium opens by a mouth, or in a few species several mouths are present.*

Mr. C. G. Lloyd,§ in monographing the genus *Tulostoma*, bases his main divisions on the nature of the mouths by which the peridia open. On this basis he establishes the following five main divisions:

"(1) Mouths definite, tubular, round, naked, more or less protruding.

"(2) Mouths definite, naked, elongated, sometimes several on the same peridium.

"(3) Mouths an indefinite torn aperture, not surrounded by a fibrillose layer.

"(4) Mouths surrounded with a fibrillose layer.

"(5) Mouths fimbriate."

Tulostoma cyclophorum, which he records from South Africa (Western Cape Province probably), is placed in the fifth division above. *Tulostoma*

* The name of the genus is also spelled *Tylostoma*, and the following appears to be the history of the name:

Tulostoma, Pers., 'Disp.,' p. 6; Fries, 'Syst. Orb. Veg.,' i, p. 139.

Tylostoma, Sacc., 'Syll. Fung.,' vii, p. 60; Lloyd (*vide* below).

† Massee, G., "British Gasteromycetes," 'Ann. Bot.,' iv, p. 86 (1889).

‡ Lloyd, C. G., "The Genera of Gastromycetes" (Cincinnati, Ohio, U.S.A., 1902.)

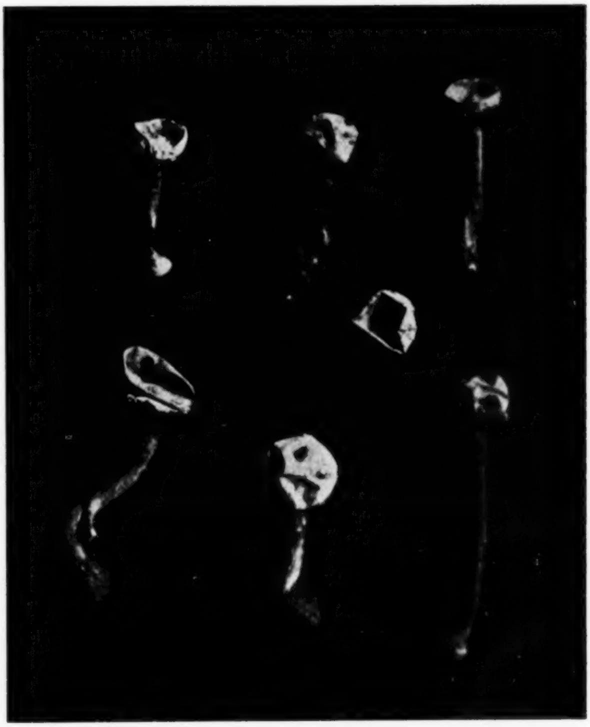
§ Lloyd, C. G., "The Tylostomeae" (Cincinnati, Ohio, U.S.A., 1906).

Lesliei belongs to the first division, and we characterise it by the following description:

TULOSTOMA LESLIEI, n. sp. (Fig. 1.)

Plants terrestrial, stalked; peridium globose, *white*, 7–9 mm. diam.; exoperidium adhering at base of peridium; *mouths definite, tubular, round, protruding*; capillitium branched, hyaline, septate, nodulose at septa; spores in mass cinnamon colour, globose, *smooth*, 3·5–4 μ diam.; stalk 1·5–2·5 cm. long × 1–1·5 mm. diam., inserted into a depression at base of peridium, longitudinally striate, hollow with a central fibril.

Habit.—Found growing in sandy soil at Durban by the writer. (Type in Natal Herbarium, P. v. d. B., No. 690.)



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ON A FUNGUS—*OVULARIOPSIS PAPAYÆ*, N. SP.—WHICH CAUSES POWDERY MILDEW ON THE LEAVES OF THE PAWPAW PLANT (*CARICA PAPAYA*, LINN.).

By Paul A. van der Bijl.

(With Plate X and one Text-figure.)

Along the coast of Natal, where the pawpaw is generally cultivated, we frequently find the under-surface of their leaves showing white powdery areas (Plate X). This is due to the growth of a fungus which may at times cover the greater portion of the under-surface of the leaves. The mycelium of the fungus creeps on the surface, and branches of the hyphae penetrate through the stomata and ramify in the intercellular spaces of the spongy parenchyma tissue of the leaves.

A "powdery mildew" does not appear to have been previously reported from the leaves of the pawpaw, and this fungus is held to be a new species, for which the name *Ovulariopsis papayae*, n. sp., is suggested. The genus *Ovulariopsis* was founded by Patouillard and Hariot* in 1900, and is characterised by the following description: Sterile hyphae epiphytic and intercellular; fertile arising from sterile, erect, simple, bearing at their apices a single, large, hyaline, subclavate conidium.

In its subclavate conidia and having the sterile hyphae both epiphytic and intercellular the genus *Ovulariopsis* resembles the genus *Phyllactinia*, Lév., which latter belongs to the Erysibaceae—a family including a number of fungi responsible for "powdery mildews."

Ovulariopsis and *Phyllactinia* are on conidial fructifications and habit evidently closely related, and the former may be in part only the conidial fructifications of the latter.

Thus far only the conidial stage has been observed in the pawpaw fungus, and should the perithecial stage subsequently come to light and prove to belong to *Phyllactinia* then this name would replace *Ovulariopsis*, as it would represent the perfect stage in the life-cycle of the fungus. Salmon,† basing his conclusions on the size of the conidia, considers

* Patouillard, N., and P. Hariot, "Enumeration des Champignons récoltés par M. A. Chevalier au Senegal et dans le Soudan occidentale," 'Journ. de Botanique,' xiv, p. 245 (1900).

† Salmon, E. S., "On the Identity of *Ovulariopsis*, Pat. and Har., with the Conidial Stage of *Phyllactinia*, Lév.," 'Ann. Myc.,' ii, p. 438 (1904).

Ovulariopsis erysiphoides, Pat. and Har., and *Ovulariopsis moricola*, Delacroix, as conidial stages of the almost cosmopolitan *Phyllactinia corylea* (Pers.), Karst. The measurements of the conidia of the above fungi are given below:

Ovulariopsis erisyphoides, 48–55 × 13–17 μ (*teste* Salmon); 60–70 × 12 μ (*teste* Patouillard and Hariot).

Ovulariopsis moricola, 48–70 × 15–23 μ (*teste* Salmon).

Phyllactinia corylea, 45–64 × 13–16 μ (*teste* Salmon).

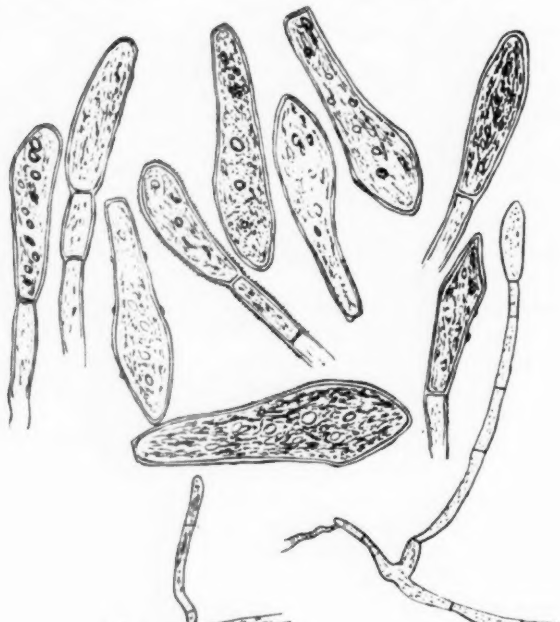

Fig 1.

From a large number of measurements we find the conidia (Fig. 1) of *Ovulariopsis papayae* to vary considerably, and the extremes are 60–90 × 14–23 μ. The majority are 72 × 14 μ. They hence exceed in length the conidia of the fungi mentioned above. We have not tried inoculating our fungus into mulberry leaves, from which host *Ovulariopsis moricola* was named, but have not observed a similar fungus on mulberry leaves. On several occasions we found mulberry trees growing in close proximity to infected pawpaw plants, but not in a single instance had the fungus spread

from the latter to the former. *Phyllactinia corylea* has thus far not been recorded from the leaves of the pawpaw, though it has a large number of host-plants, and Salmon* records it from mulberry (*Morus alba*) from Japan. In South Africa it has to date not been found on this host.

We give the following brief diagnosis of the pawpaw fungus:

OVULARIOPSIS PAPAYAE, n. sp.

Sterile hyphae hyaline, epiphytic, penetrating interior of leaf through the stomata and ramifying in the intercellular spaces of the spongy parenchyma; conidiophores arising from the sterile hyphae, erect, cylindrical, pluriseptate, up to $200\,\mu$ long, $7\,\mu$ diam.; conidia large, borne singly at apex of conidiophores, subclavate, $60–90 \times 14–23\,\mu$, majority $72 \times 14\,\mu$; conidiophores and conidia usually smooth, rarely beset with fine projections.

Habit.—On under-surface of live leaves of *Carica papaya*, causing "powdery mildew." Common along Natal coast. (Type in Natal Herbarium, P. v. d. B., No. 924.)

* Salmon, E. S., "The Erysiphaceae of Japan," 'Bull. Torr. Bot. Club,' xxvii, pp. 438–439, 445 (1900).

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NOTE ON *LYSURUS WOODII* (MacOWAN), LLOYD.

Paul A. van der Bijl.

(With Plate XI.)

In 1880 Kalchbrenner* published under the name *Anthurus Woodii*, MacOwan, the description of a fungus collected by J. Medley Wood at Inanda, Natal. Since that date until 1917, when Mrs. J. G. Hackland, of Ixopo, Natal, favoured me with the specimens, Figs. 1–3, which form the subject of this paper, no similar fungus was collected in Natal, or for that matter in South Africa. The specimens were found in a rhubarb trench, and though at my request Mrs. Hackland subsequently made a thorough search for more material, none could be obtained. When received the fungus was referred as above, and a photograph of it was forwarded to Mr. C. G. Lloyd, Ohio, U.S.A. From the photograph Mr. Lloyd referred it to *Lysurus Gardneri*, Berk., and in publishing† the photograph mentioned that in his mind there was no doubt of this being the original *Anthurus Woodii*.

Considerable interest has recently been taken in the identity or otherwise of the Ceylonese plant *L. Gardneri*, Berk., with the Australian *L. australiensis*, Cooke. Petch‡ made comparative studies of these two plants and has shown that they are entirely different; indeed the differences are so great as to warrant placing *L. Gardneri* in a new genus, for which he suggests the name *Pharus*.

The separation of *Lysurus Gardneri* into the new genus *Pharus* is based on differences in the glebiferous layer. Amongst other points of difference Petch§ showed that whereas in *L. australiensis the glebiferous layer is composed of a series of closely set horizontal ridges, in L. Gardneri (now Pharus Gardneri (Berk.), Petch) it is slightly furrowed transversely, and the whole surface minutely granular*, the granules being the ends of thin processes or the irregular edges of contorted plates, so closely packed that their outer ends form a continuous surface.

* Kalchbrenner, K.—Phalloidei novi vel minus cogniti, Budapest, 1880, p. 23.

† Lloyd, C. G.—Mycological Notes, No. 55, p. 793, August, 1918.

‡ Petch, T.—Further Notes on *Colus Gardneri* (Berk.), Fisher, Trans. British Mycological Soc. VI, 122 (1919).

§ Petch, T.—*Loc. cit.*, p. 127.

Fig. 2 is a photograph of the glebiferous layer, after the removal of the gleba, of the Natal *Lysurus*, and we at once notice that it is composed of smooth wrinkles resembling that of *L. australiensis* and differing entirely from that of *L. Gardneri*. Another point in which the Natal plant differs from *L. Gardneri* is that the arms in the former are not borne on separate stalks of their own, a condition which exists in the latter (*vide* fig. 38 in Lloyd's 'Synopsis known Phalloids.') In this it departs from *L. Gardneri* and resembles *L. australiensis*. Illustrations of the latter (*vide* fig. 835 in Lloyd's 'Mycological Notes,' No. 43) shows the "head" separated from the stalk by a constriction, and this is mentioned as usually present. In the Natal *Lysurus* no such constriction is present. The glebifereous layer, after removal of the gleba, is white in the Natal plant, which in this respect resembles *L. australiensis* and differs from *L. Gardneri*, for which the glebiferous layer is recorded as dark olivaceous.

The original illustration* of *Lysurus Woodii* shows the "arms" as entirely free and the gleba is given as occurring on the outside of the arms. On this presumed latter character the plant was placed in the genus *Anthurus*.

Lloyd,† from an examination of the cotype at Kew, writes: "While it is unsafe to draw conclusions from dried specimens, we believe the species is a *Lysurus* entirely distinct from the genus *Anthurus*, and that Kalchbrenner misconceived and misdrew the illustration." The plant herein referred as *L. Woodii* has no resemblance to an *Anthurus*.

The arms of *L. Woodii* are from the specimen seen six in number; two were united at the apex by a narrow tube (Fig. 2); in section the arms are triangular. Longitudinally the glebiferous layer extends the entire length of the arms and transversely nearly round the arm, leaving only a shallow longitudinal furrow free from gleba. The wrinkles of the glebiferous layer are ·3–·5 mm. broad, and as in *L. australiensis* are continued from arm to arm at the base. The wall of the stalk has three layers of chambers. The entire plant measures 6 cm. high by 1 cm. diameter in the stalk region. The "cap" is 1·7 cm. long and the gleba dark. The spores are minute, smooth, colourless to very faint greenish yellow, elliptical and 4–4·8 by 1·6 μ in size.

The relationship of *L. Woodii* must be with those species having a similar glebiferous layer—*L. australiensis*, *L. borealis* and *L. Clarazianus*. Judging from published illustrations we would consider it nearest to *L. borealis*, but much smaller. Until more is known about *L. Woodii* and sufficient material of it collected for comparative studies we consider it best regarded as a distinct species related and close to *L. australiensis* and *L. borealis*.

* Kalchbrenner, K.—*Loc. cit.*, plate 3, fig. 2.

† Lloyd, C. G.—Synopsis known Phalloids, p. 40.

Fig. 3 represents a transverse section through the egg of *L. Woodii*. The microscopic details of the Natal *Lysurus* are now recorded for the first time.

EXPLANATION OF PLATE XI.

FIG.

1. *Lysurus Woodii* (MacOwan), Lloyd. Natural size.
2. Two "arms" of *L. Woodii* with gleba removed and showing the wrinkled glebiferous layer. Note also the two "arms" are joined at the apex and the glebiferous layer is continuous at the base from "arm" to "arm."
3. Transverse section through egg of *L. Woodii*.

Fig. 1.

Fig. 2.

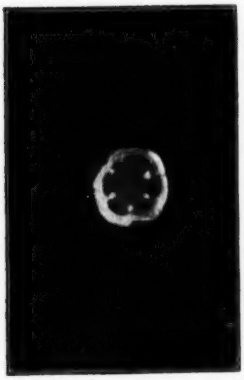

Fig. 3.

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A PREHISTORIC ROCK-SCULPTURE FROM THE NORTH-EASTERN TRANSVAAL.

By C. Pijper.

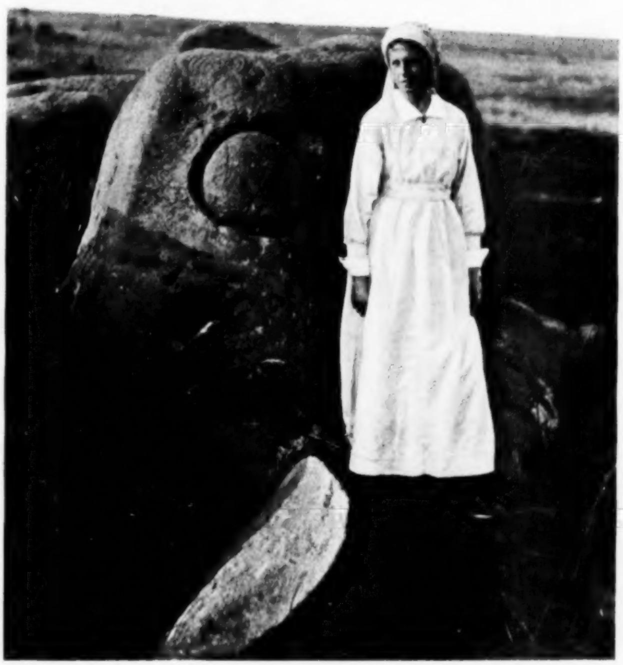
(With Plate XII.)

The stone, pictured herewith, was discovered by me in the Lijdenburg district, in the North-Eastern Transvaal, not far from the stones engraved with cup-and-ring markings, of which I gave a description in the 'South African Journal of Science,' March–April, 1919.

There can be no doubt that the circular "knob" is the handiwork of man; it is so very nearly circular, in fact as nearly circular as we can imagine it was possible to make it with crude stone implements only, without the help of compasses or similar instruments; moreover, in the original the tool-marks are unmistakable.

As the "moat" around the "knob" has, from length of time, once more assumed the colour of the original rock, this "piece of sculpture" must date from long, long ago.

As far as I know, no similar rock-sculpture has ever been described from South Africa, and this circumstance I think justifies the publication of this photo, even although it is at present impossible to say by whom this piece of work was executed or what it was intended to represent. It seems most likely, however, that it was meant to be an image of the sun; is it possible that the semi-circular lines higher up on the rock were intended to represent the moon?



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THE ACTION OF *URGINEA BURKEI* (BAKER).

By J. W. C. Gunn.

(From the Department of Pharmacology, University of Cape Town.)

Urginea Burkei (Baker), a plant of the Natural Order of *Liliaceae* more commonly known as the Transvaal slang-kop, is responsible for many fatal cases of poisoning among sheep and other stock in certain parts of Africa. Poisoning is usually due to animals eating the young shoots and leaves. The symptoms are vomiting and diarrhœa, and, in fatal cases, paralysis and coma. Several investigators have recorded similar effects when animals are fed experimentally with the bulb, but I am unaware of any experimental work done to test the precise pharmacological action of the drug. The present research was performed to elucidate this action.

In the experiments to be described I used preparations from the bulb, for a supply of which I am indebted to Dr C. F. Juritz, of the Agricultural Research Department. I have not yet been able to obtain any of the leaves.

Part I.—Experimental.

a. Preparation of Tincture and Extract.

The dried bulb was powdered, macerated in 60 per cent. alcohol for three days, and then strained through three folds of linen. The marc was percolated with two further lots of 60 per cent. alcohol.

The extract was prepared from the tincture by heating it to dryness over a water-bath.

In the experiments, except where stated, a tincture, of which 10 c.c. were equivalent to 1 grm. of the dried bulb, and an extract, of which 1 grm. was equivalent to 5·93 grm. of the bulb, were used. No attempt was made to isolate any pure principle.

b. Local Action.

The powdered bulb is very irritating, and inhalation of small quantities produced sneezing, lachrymation and coughing.

A solution of the extract applied to the frog's mesentery induced a marked inflammatory reaction in a few minutes.

Administration of 0·1 grm. of the extract to a cat through a stomach-tube was followed by vomiting and diarrhœa. Inflammation of the stomach and intestine was found on post-mortem examination.

c. General Action.

The general action is seen best when subcutaneous injections of a solution of the drug are given to frogs or mammals. In many cases when it was administered by mouth the local action on the gastro-intestinal tract was seen, but no other action. The reason of the comparative inability of the extract to produce general symptoms in such cases may be: (i) Loss of the greater portion in the vomit; (ii) destruction of the active ingredient by the digestive juices; or (iii) very slow absorption.

(a) *General Action on Frogs.*

About fifty experiments were done, and all gave similar results. The following is a typical example:

Frog, *Rana platana*, male, weight 65 grm.

11 a.m.: 3·25 mgrm. of extract of *Urginea Burkei* dissolved in 0·5 c.c. of Ringer's solution injected into anterior lymph-sac of thigh.

11.5 a.m.: Frog has been jumping about and showing signs of increased activity.

11.15 a.m.: Spontaneous movements have ceased. Frog lies passive, with fore limbs extended by side and hind limbs flexed at every joint. Able to turn over if laid on back. Reflexes greatly diminished.

11.35 a.m.: No power of movement. Respirations very slow.

12.5 p.m.: Chest opened. Heart very slow. Auricles beating twice for one beat of ventricle. Apex of ventricle pale.

12.15 p.m.: Heart has ceased to beat. Ventricle pale and contracted; auricles engorged and distended. The gastrocnemius muscle responds to direct stimulation and to stimulation of the sciatic nerve.

Variations.—The diminution of conductivity, resulting in failure of alternate impulses to pass from auricle to ventricle, was seen in about one-third of the cases. In several experiments the ventricle stopped in diastole or only partial systole, but a slight mechanical stimulus applied to the ventricle was sufficient to send it into complete systole.

(b) *Dose to produce Systolic Arrest in One Hour.*

Method.—A tincture was used in which 5 c.c. were equivalent to 1 grm. of the bulb. Most of the alcohol was driven off by gentle heat and the tincture made up to the original bulk with Ringer's solution. A measured amount of this was made up to 0·5 c.c. with Ringer's solution and injected into the ventral lymph-sac of a frog. At the end of one hour the frog was pithed and the heart examined.

Results.—Twenty-four experiments with varying doses were made, and it was found that the dose required to produce systolic arrest in one hour was 0·006 c.c. of 20 per cent. tincture per gramme of body-weight of frog. It is

noteworthy that in many cases at the end of the hour there was little evidence of loss of power in the frog's muscles, but the cardiac action was well developed.

The frogs used were the South African variety, *Rana platana*. They were treated with strophanthin that had been used in England on *Rana temporaria*. The English and South African frogs required the same dose per gramme of strophanthin to produce systolic arrest of the heart.

(c) *General Action on Mammals.*

In thirty-eight experiments the tincture or extract of *Urginea Burkei*, dissolved in Ringer's solution, was injected subcutaneously into rats, rabbits and cats.

A few minutes after injection of a lethal dose the respirations were greatly accelerated, and there was, as a rule, profuse salivation. The animal soon began to sway from side to side and to drag its hind legs when walking. The muscular weakness progressed, and soon afterwards the animal lay down on its side apparently quite powerless. The respiration was slow, and, in many cases, irregular and gasping. Coma developed, in a few instances preceded by convulsions, and a few minutes afterwards the heart and respiration ceased. No vomiting occurred, but three animals made retching movements.

Sublethal doses produced symptoms of less severity. A dose less than one-third of the minimal lethal dose was followed by depression or salivation, or had no apparent effect.

The frequent occurrence of vomiting when the drug was given by mouth, and its absence when intravenous or subcutaneous injections were made, would point to the chief cause of vomiting being reflex from irritation of the stomach.

(d) *Minimal Lethal Dose for Rat and Rabbit.*

The minimal lethal dose of the extract for the rabbit by subcutaneous injection is 0·025 grm. per kilogramme of body-weight, and for the rat 0·4 grm. The rat therefore has a certain degree of natural tolerance for the poison as compared with the rabbit, the minimal lethal dose being sixteen times as great.

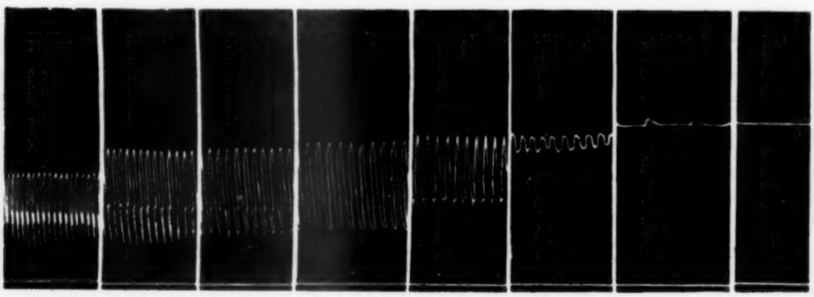
D. Action on the Circulatory System.

(a) *Action on the Isolated Frog's Heart.*

The contractions of the isolated frog's heart were recorded by perfusion through a cannula tied into the inferior vena cava. A second cannula was inserted into the left branch of the aorta and all the other vessels were tied. Ringer's solution was perfused until the heart became regular, then a solution of the tincture or extract was perfused.

The first effect is an increase in the extent of systole. Very soon the rhythm of the heart is slowed. The output per minute, measured by the outflow from the aortic cannula, is increased. The slowing becomes more marked, and after some time the relaxation of the ventricle is impaired and the output of the heart decreases. These changes continue, gradual increase in the contraction and slowing and diminution in the diastolic relaxation and outflow, until the heart is finally arrested in complete systole.

Fig. 1 shows the effect of perfusing the isolated frog's heart with 1 in 5000 extract of *Urginea Burkei.* A is the normal heart-beat. B to H are the effects produced at three-minute intervals after perfusion. The heart is stopped in 21 minutes in systole.



A B C D E F G H

Fig. 1.

(b) *Action on the Frog's Heart* in sitû.

The tracings obtained from the frog's heart *in sitû* were practically a reproduction of those obtained from the isolated heart. With sufficient dosage there was stoppage of the heart, the ventricle in systole and the auricles in diastole.

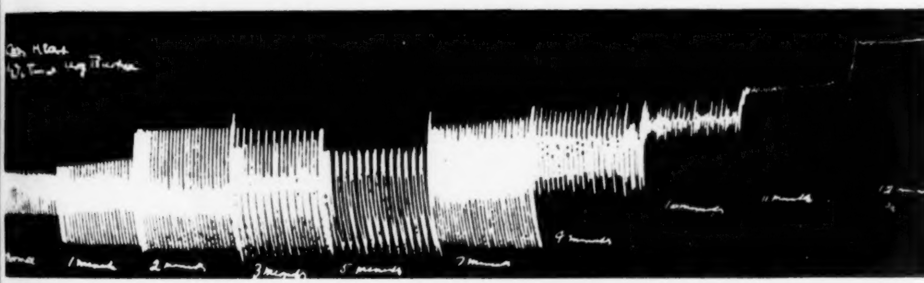
(c) *Action on the Isolated Mammalian Heart.*

Rabbits, cats, rats and guinea-pigs were used in the experiments. The animal was killed and the heart quickly removed. A cannula was inserted into the aorta and the heart perfused through the coronary arteries with oxygenated Locke's solution at 37° C. The tip of the ventricle was attached to a lever writing on a smoked drum.

The first effects noticeable on adding tincture or extract of slang-kop to the perfusing fluid are increase in systole and diastole and slight slowing. The subsequent events follow one of three courses: (1) The heart remains slow but regular; the extent of systole increases, while that of diastole, after the preliminary increase, decreases until the heart is arrested in systole like

the frog's heart. Fig. 2 shows the effect of perfusing the cat's heart with 1 in 200 tincture of *Urginea Burkei*. The upstroke denotes systole. A is the normal heart-beat. B to J show the effect on the heart when the experimental solution has perfused for 1, 2, 3, 5, 7, 9, 10, 11 and 12 minutes respectively. This is the most characteristic action of slang-kop on the mammalian heart.

(2) Heart-block may appear. This may be sinu-auricular, the heart suddenly beating at half its previous rate, but is more commonly auriculo-ventricular, the ventricle beating at a slower rate than the auricle. Very soon the block becomes complete, no impulse passing from auricle to ventricle. In these cases it is noticeable that the tone of the ventricle increases as the drug is perfused, even after pulsations have ceased, and it soon is firmly contracted.



A B C D E F G H I J

Fig. 2.

(3) The heart after the preliminary slowing may become quick and irregular. Pulsus alternans and extra-systoles appear. These rarely pass off, but if they do the heart may finish as in (1) or (2). More commonly however, the extra-systoles are the precursors of fibrillation of the auricles and ventricles, and the heart ceases after a short period of extreme irregularity.

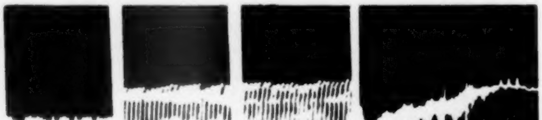
The rat's heart is less susceptible to the action of the poison than the cat's or rabbit's heart.

(d) *Action on the Mammalian Heart* in sitû.

Method.—The animal—rabbit or cat—was anæsthetised with paraldehyde or urethane followed by ether. Cannulae were inserted into the trachea, left carotid artery and right jugular vein. Artificial respiration was commenced and the thorax opened in the middle line. A cardiometer, connected by rubber tubing to a recording tambour, was placed round the heart and the

pericardium tied round it. The rate and volume of the heart were thus recorded.

Results.—With small doses the heart is slowed and systole increased, and the heart empties itself more completely at each beat. With fatal doses the slowing is very transient and soon gives place to quickening and irregularity, with onset of fibrillation and arrest of the heart in one or two minutes. In one case well-marked heart-block was seen. The action of slang-kop on the mammalian heart *in sitû* differs from its action on the frog's heart and also the isolated mammalian heart in that the heart *in sitû* is arrested in diastole. The preliminary slowing has a different cause from the slowing seen in the isolated mammalian heart, which can only be due to an action of the drug on the heart itself or the vagus terminations in the heart. The slowing in the intact animal is not seen if the vagi nerves be cut, and is therefore due to direct stimulation of the vagus centre by the



A B C D

FIG. 3.

toxic substance, or to indirect stimulation following the rise of blood-pressure as in the case of adrenalin. Fig. 3 shows the movements of the heart of a cat (weighing 2340 grm.), recorded with the cardiometer. The downstroke denotes systole. A is the normal heart-beat. B shows the movements one minute after injecting 0·5 c.c. of tincture of *Urginea Burkei* into the jugular vein: the heart is slowed, and systole and diastole are increased. C shows the effect at the end of two minutes. D shows the terminal fibrillation, beginning in three minutes, and arrest of the heart in diastole in less than four minutes.

(e) *Effect on Blood-pressure.*

In most of the experiments the blood-pressure from the carotid artery and the heart-volume, as shown by the cardiometer, were recorded simultaneously. After injection of slang-kop there is a large and persistent rise of blood-pressure, commonly equal to 50 or 60 mm. of mercury, but sometimes much more. With the onset of irregularity the blood-pressure falls.

Fig. 4 shows a rise of pressure of 120 mm. after injection of 0·5 c.c. of tincture of *Urginea Burkei* into the jugular vein of a cat weighing 4350 grm.

(f) *Action on Blood-vessels.*

The volume of an isolated loop of intestine was recorded with the plethysmograph, as shown in Fig. 5; the line I–V denotes intestinal volume.

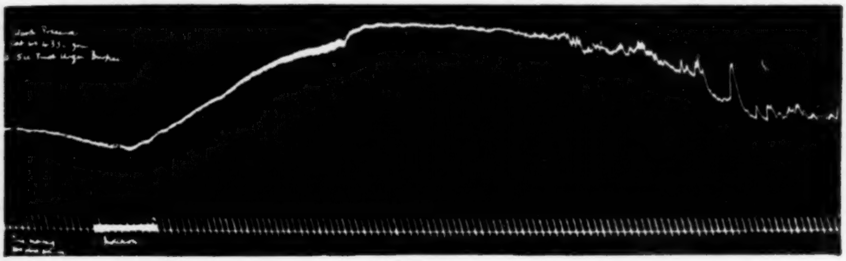


Fig. 4.

Injection of 0·5 c.c. of tincture in this case causes a rise of blood-pressure of 30 mm. This is accompanied by a decrease in the intestinal volume, indicating constriction of the vessels. A second injection produces a similar result. (The constriction is not as great as the tracing would appear to show, as the movement of the lever was magnified thirty times, and the tambour was small.) The action is on the vessel-wall, as it is still seen after the autonomic nerve-endings are paralysed with a preliminary injection of ergotoxine.

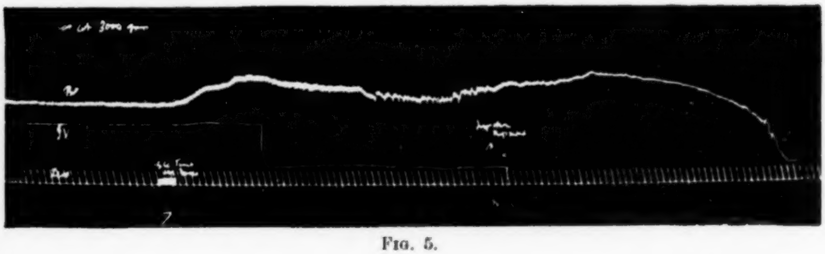


Fig. 5.

The effect on the coronary arteries was much less pronounced, and with small concentrations the vessels were dilated and the outflow increased.

E. Effect on the Kidney Secretion.

The diuretic action was studied by measuring the flow of urine from the ureters of rabbits, before and after administration of the drug. Small doses

almost invariably caused an increase of urine, but large doses caused a decrease, in a few cases preceded by a slight augmentation of the flow. It is probable that the urine is diminished in those cases where the renal vessels are so constricted as to impair the blood-supply of the kidney.

F. Action on Unstriped Muscle.

The movements of the isolated uterus and intestine of the cat and rabbit were augmented by 1 in 500 tincture of slang-kop.

Part II.—Discussion.

From these results it will be seen that the action of *Urginea Burkei* is the same as that of the digitalis group of bodies. This group includes a number of substances of great medicinal value, the most important being digitalis, strophanthus and squill.

Squill is obtained from *Scilla maritima*, a plant of the same natural order as, and of similar appearance to, slang-kop. The action of the two plants is almost identical, and the toxicity to the frog is the same. Slang-kop would seem to be slightly more toxic to mammals. It is possible that *Urginea Burkei* might replace squill in South Africa, and in fact it may be found superior. How far the action is produced when slang-kop is given by mouth must be determined, and this is being investigated further.

I beg to thank the Advisory Board of Industry and Science for bringing this subject to my notice as one suitable for research.

Summary.

The results of a large number of experiments show that *Urginea Burkei* (Baker), the Transvaal slang-kop, has the same actions as the digitalis bodies, and suggest its possible use as a South African substitute for squills.

COLOUR AND CHEMICAL CONSTITUTION.

PART XII.—THE CALCULATION OF COLOUR FROM THE TAUTOMERIC THEORY.

BY JAMES MOIR.

The scheme suggested in Part X of this work for calculating the colours of the triphenylcarbinol dyes, while no doubt of considerable practical importance, has two great drawbacks from the point of view of chemical theory, viz.: (1) that the parent-substance, fuchsene, of wave-length 593, may be wholly imaginary, and (2) that no light is thrown on coloured substances of smaller complexity or of different chemical families.

In the search for a general and fundamental theory of colour I have examined all that have been put forward in the last forty years, an excellent summary of which appears in E. R. Watson's Colour in Relation to Chemical Constitution (Longmans, 1918). It is evident first of all that no one theory fits all cases, from diazomethane to indigo for example. The most promising from a quantitative point of view (*i. e.* leading to the possibility of calculating colour with some exactitude), appeared to be the Watson-and Meek modification of Hewitt's suggestion that depth of colour depends on length of continuous tautomeric change or alternation of single and double bonds in the molecule (*l. c.*, pp. 87–91).

I have therefore analysed my observations of the wave-lengths (absorption-centres) of all the common dyes to see whether numerical values in wave-length could be assigned to each possible kind of tautomerism, which could then be added up to give a result approximating to that observed in the dye. This I found to be the case, and the main part of this paper will be found to consist of calculations of colour, with the observed figure appended for comparison. It will be seen that the theory embraces many other classes of coloured substances than the "aniline dyes."

The additive property of colour has been sufficiently demonstrated in the earlier sections of this work; it now remains to give it a physical basis. The reader has first to remember that frequency of vibration is the inverse of periodic time, and that wave-length is inverse to frequency. It follows that wave-length is directly proportional to periodic time. The simplest assumption therefore is that the observed wave-length (absorbed by a highly-dilute coloured solution) is physically caused by an electron travelling through a sinuous orbit, which is completed (on the average) in a periodic time during which light would travel through that distance (*e. g.* 602 $\mu\mu$

for Michler's hydrol in water). The additive property means that the sinuous orbit is made up of roughly semicircular portions through which the electron passes in turn from one end of the chain to the other, *e.g.*:

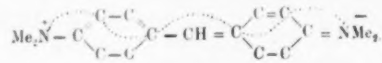


Fig. 1.—Michler's hydrol.*

so that the total periodic time is the sum of the separate periodic times taken in each loop. Also at this stage I may mention that there is not much difference between the values of the different tautomerisms, so that 5 loops give a wave-length in the middle of the spectrum (λ 500 in unloaded molecules); 4 loops give about λ 400, viz. yellow substances; 3 loops give about λ 300 (colourless substances with photographable absorption bands); whilst substances with less than 3 tautomeric loops, unless very heavily loaded with side-groups, are in general colourless, even to the photographic plate.

It is to be noted that such a sinuous orbit would not be expected to have an exact and constant periodic time, but only an average one. This explains why absorption-bands are diffuse and not narrow lines as in the case of sodium vapour, where the periodic time is constant. The diffuseness of the bands means a diffuse periodic time, *i. e.* a periodic time affected by perturbations, to use the astronomical analogy.

It is probable that the path of the electron is not as shown in the diagram, Fig. 1, namely passing *through* carbon atoms, but that the path goes in between the successive atoms of the tautomeric chain, making in the above case ten sinuosities instead of five (eleven if the particle goes *round* the final atom to continue the orbit in the reverse direction—Fig. 2).

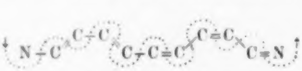


Fig. 2.—Path of electron.

The result of my calculations is that (1) the tautomerism

$$>C-CH=C<$$

has a value of 103 $\mu\mu$ in wave-length, (2) the tautomerism

$$>C-CH=O$$

has a value of 94, and (3) the tautomerism

$$>C-CH=NH$$

* For clearness, the hydrogens and the non-tautomeric double bonds are omitted.

has a value of 98. All other parts of a molecule have *small* values: *any* group attached to the inner *end* of a tautomerism and itself incapable of tautomerism has a value of about $7\frac{1}{2}$, viz. 7 for small groups, *e. g.* Me, Et, Cl, and 8 for large groups such as iodine or phenyl. Groups of the above kind, but attached to the *middle* of the tautomerism, have double value, viz. about 15 (14 for methyl, 16 for iodine or phenyl). An anomaly may be noted, namely that groups on the *final* nitrogen of tautomerism 3 have this double value also, the tautomerism

$$Me_2N - CH = C<$$

having the value of 126 (viz. 98 + (2 × 14)).

Now in a colour containing a phenol-ring, the following dissection of the ring is to be imagined:

The part on the left within the thick lines is the CCO tautomerism loaded with a non-tautomeric group CH in the *middle*; its value is therefore 94 + 15 = 109. The next tautomerism is CCC loaded with a group CH (rest of benzene-ring), this time at its end; its value is thus 103 + 7 = 110. The CH in the square of the diagram is common to both tautomerisms. The total value of the phenol-ring is thus 219, and this is CCO + CCC + 22. Thus the non-tautomeric portion of the benzene-ring – CH = CH – has always a value of 22.

In the same way the value of the aniline or para-aminophenyl-ring is CCN + CCC + 22 = 223; and the value of the para-dimethylaminophenyl-ring is 126 + 103 + 22 = 251.

Any halogenated phenol-ring will have the value 219 + 7 = 226 if the halogen is *ortho* to the hydroxyl, and the value 219 + 15 = 234 if the halogen is *meta*, the one being a terminal and the other a central loading of the tautomerism (if the substituent is large, viz. iodine, the value is one or two more). Alkyl derivatives have the same values, viz. 7 or 15, if attached to carbon.

Similarly halogenated aniline-rings have the values 223 + 7 = 230 if *ortho*, and 223 + 15 = 238 if *meta*, and so on, all the substituents having nearly the same value if non-tautomeric, and everything being additive. Examples will be given later on in the paper. A few concrete cases may now be studied:

(1) *Dioxybenzhydrol (aqueous alkali).*

The formula is

in which only the tautomeric double-bonds are written. This consists of two of the phenol- or para-oxyphenyl-rings, joined by a middle tautomerism:

$$>C-CH=C<.$$

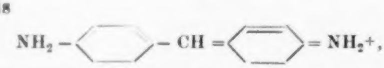
The calculated wave-length is therefore $2\times 219+103=541$. The observed λ was about 539 (own observation).

(2) *Benzaurine in alkali (aqueous).*

This is the phenyl-derivative of the foregoing, with CPh in the middle instead of CH. As this is a middle loading, the value is 14 to 16 according to the size of the group. Taking 16 for phenyl, the calculated value for benzaurine is $541+16=557$. The observed λ was 553. The other two bands at λλ 370 and 290 are, in my opinion, due to shorter tautomerisms of three and two units respectively.

(3) *Diaminobenzhydrol (neutral chloride in water).*

The formula is



and consists of two para-aminophenyl-rings united by the tautomerism CCC. The calculated wave-length is therefore $2\times 223+103=549$. I have observed in a crude product λ 548. Watson (*l. c.*, p. 88) gives λ 564 *in alcohol*. It is to be noted that in alcoholic solution such dyes are not ionised, *i. e.* are loaded with chlorine on the nitrogen, and therefore give a higher wave-length than in water.

(4) *Doebner's violet in water.*

This is the C-phenyl-derivative of the foregoing, related to No. 3 as No. 2 is to No. 1. The calculated wave-length is therefore 16 more than 549, or 565. The observed λ was 562. Meyer and Fischer (Berichte, 1913) give λ 570 in alcohol, with two lower bands at λλ 400 and 300 due to shorter tautomerisms.

(5) *Michler's hydrol in water.*

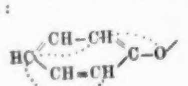
The formula is as in Fig. 1. The calculated colour is $2\times(Me_2NCC)+CCC$ or $2\times 251+103=605$. Observed in water λ 602, in alcohol λ 610.

(6) *Malachite-green in water.*

This is the C-phenyl-derivative of Michler's hydrol (Watson, *l. c.*, p. 90); hence its calculated wave-length is $16+605=621$. Observed λ 619 in water.

(7) *Sodium phenate and* (8) *aniline.*

This is an example of a simple triple tautomerism in which the whole benzene-ring takes part:

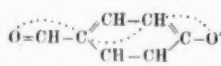


(or NH_2).

For the former substance, calculation gives CCO + 2CCC = 94 + 206 = 300; for the latter we have CCN + 2CCC = 98 + 206 = 304. The observed values are both about λ 290 (Tuck, J.C.S., 1909). It is to be noted that free phenol and aniline hydrochloride give entirely different spectra, which cannot be calculated.

(9) *Sodium paraoxybenzaldehyde.*

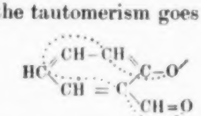
This is



in which, as before, the non-tautomeric double bond is not shown. This consists of the tautomerisms CCO + CCC + CCO loaded with the ring residue – CH – CH –. The calculated figure is therefore 94 + 103 + 94 + 22 = 313. The observed figure (? in alcohol) is about λ 330 (Baly, J.C.S., 1907). The substance is colourless.

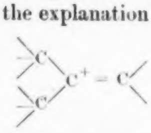
(10) *Sodium salicylaldehyde.*

This is yellow because the tautomerism goes right round the ring:

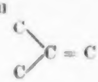


It consists of CCO + CCC + CCC + CCO, and the calculated figure is: 2 × 94 + 2 × 103 = 394. Baly observed λ 388 (*l. c.*).

At this stage we will now consider the three symmetrical aniline dyes, aurine, parafuchsine and crystal-violet, which have always been a puzzle to the colour chemist because their colours are lower than those of the corresponding unsymmetrical compounds, benzaurine, Doebner's violet and malachite-green. I find that the explanation is that the tautomerism



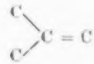
has a lower value than the simple tautomerism CCC, the existence of two simultaneously available paths apparently making the orbit smaller and the periodic-time less. The value is about 96. It is also to be noted that the whole tautomeric chain in these dyes is no longer than before, viz. 5 tautomerisms, not 8, because the orbit can only go through two of the benzene-rings at a time, never through all three in succession. Consequently aurine is a loaded dioxybenzhydrol, parafuchsine is a loaded diaminobenzhydrol, and crystal-violet is a loaded Michler-hydrol. The general formula being $C^+(C_6H_4X)_3$, my supposition is that the colour is due to *two* groups C_6H_4X united by the tautomerism



of value 96, whereas in the unsymmetrical series $PhC^+(C_6H_4X)_2$ the two groups C_6H_4X are united by the tautomerism $C - CPh = C$ of value 103 + 16 = 119. We will now calculate these dyes.

(11) *Aurine-sodium in water.* $C^+(C_6H_4O\diagup)_3$.

According to the above theory we have *two* active rings $C_6H_4O\diagup$ of value 219 each, plus



of value 96. This gives 438 + 96 = 534. This agrees exactly with observation.

(12) *Pararosaniline in water.* $C^+(C_6H_4NH_2)_3$.

Here we have two active rings $C_6H_4NH_2$ of value 223 each, plus the same tautomerism; hence the calculated value is $2 \times 223 + 96 = 542$. Observation gives λ 543.

(13) *Crystal-violet (N-hexamethylpararosaniline).* $C^+(C_6H_4NMe_2)_3$.

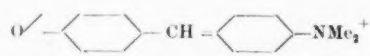
Here we have two active rings $C_6H_4NMe_2$ of value 251 each, plus the same tautomerism; hence the calculated value is 502 + 96 = 598. Observation gives λ 596.

It is known that in the case of Nos. 12 and 13 the addition of acid changes the colour, fuchsine becoming purple and crystal-violet green. The true explanation of this now lies to hand, viz. that the symmetry is destroyed, leaving two of the groups as $C_6H_4NH_2$ whilst the third becomes the ion $C_6H_4NH_3^+$. The dyes become then derivatives of the *unsymmetrical* class mentioned just above $PhC(C_6H_4X)_2$. Thus purple (acid) fuchsine is a substituted Doebner's violet, and green (acid) crystal-violet is a substituted malachite-green. The ion $C_6N_4NH_3^+$ and the ion $C_6H_4NHMe_2^+$ are non-tautomeric and appear both to have the value 27; if this number be substituted for the value 16 used for plain phenyl in calculating Doebner's violet and malachite-green, the calculated results are 549 (diaminobenzhydrol) + 27 (or 576), and 605 (Michler-hydrol) + 27 (or 632), which are precisely the observed figures in acid parafuchsine and acid crystal-violet.

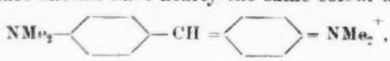
(14) *Paraoxy-derivative of malachite-green.*

This interesting substance is another *crux* of the colour chemist, being blue when neutral and purple-pink when alkaline.

On my theory the alkaline phase should have nearly the same colour as the substance



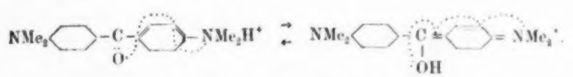
and the neutral phase should have nearly the same colour as



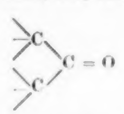
(Michler-hydrol). The observed wave-lengths are λλ 578 and 608 respectively. Oxydimethylaminobenzhydrol has not yet been observed, but its calculated wave-length is 219 + 103 + 251, or 573. Its phenyl derivative (dimethylaminofuchsone of Part X) has been observed, giving λ 586, whence oxydimethylaminobenzhydrol itself should have λ = 586 minus 16 or 570. Taking the unknown, therefore, to have wave-length 571, and remembering that Michler-hydrol has λ 603, we see that the two colours of paraoxymalachite-green (bis-dimethylamino-fuchsone) are both about 6 units higher than those of the simple benzhydrol compounds, this being the allowance for the non-tautomeric group or load, $C_6H_4NMe_2$ or C_6H_4OH respectively. The theory, therefore, not only accounts for two colours in this substance, but enables them to be calculated.

(15) *Michler's ketone* (salt in water).

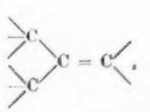
The formula is



The substance is yellow, and there are only three tautomerisms, as shown in the formula. The tautomerising ring $C_6H_4NMe_2$ has been shown to have the value 251; adding the tautomerism CCO of value 94 and 16 for the benzene-ring load (non-tautomeric) we get 361 as the calculated wave-length. The observed figure is about λ 364 (λ 368 in alcohol, Watson, p. 88). The small difference is due to the load on the benzene-ring outside the tautomerism. In previous paragraphs (substances 13 and 14) it is shown that substitution in the benzene-ring outside the tautomerism causes small but variable changes in the value (16) assigned to plain phenyl. These small differences are at present anomalous but do not much affect the validity of the theory. In this particular case, too, one may note that the tautomerism



may be of lower value than the simple tautomerism CCO on the analogy of the tautomerism

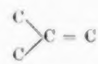


in which case the calculated value would be about seven units lower.

An explanation is still required for the marked yellow colour of the dye auramine, which is derived from Michler's ketone by replacement of O by

NH, and therefore should have λ about 365, whereas it is really about 420. Two other partial anomalies are fuchsimonium chloride and its dimethyl-derivative, which have *very broad* absorption bands at λλ 430 and 460 respectively in alcohol. The formula

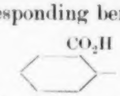
corresponds to the tautomerism



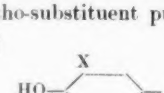
combined with the $C_6H_4NH_2$ ring and two phenyl loads. This would be 96 + 223 + 32 = 351; similarly the dimethyl derivative would work out at 379, both of which calculations are about 80 units too low. Now colour and broad bands similar to these are obtainable from malachite-green and crystal-violet by adding an excess of acid, the observed wave-lengths being about λ 438 and λ 417 respectively. It is evident that these five cases cannot be explained on an exact quantitative basis, and I suggest that in all of them the tautomerism penetrates into one of the benzene-rings in a highly perturbed orbit, thus accounting for both the breadth of the band and its abnormally high position; the orbit would thus be of the following type in which the irregular orbit varies in value between 80 and 100.

Fuchsonedimethylimonium salt λ 460 in alcohol.

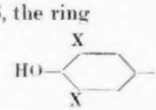
Having now shown the weaker points of the theory, it may be well to show how it explains the colours of the phthaleins or other well-known substances. Since the CO_2H group of the phthaleins is outside the tautomerism it makes scarcely any difference; observation shows that any substituted phenolphthalein has a spectrum which is only one to two units different from that of the corresponding benzaurine. Thus the central



group may be taken to be of value + 18 when phenyl is + 16. Again, it is shown on p. 207 that an ortho-substituent puts the value up by 7 and a meta by 15. Hence the ring

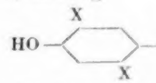


has a value of 219 + 7 = 226, the ring

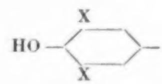


has a value of 233, the ring

has a value of 219 + 15 = 234, the ring



has a value of 241, and so on. In the *p*-amino-rings the values are 4 greater in each case. To calculate ortho-tetrabromophenolphthalein therefore we split it into two rings



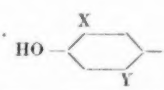
plus the tautomerism

$$\begin{array}{c} C - C - C, \\ | \\ C_6H_4CO_2H \end{array}$$

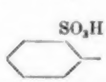
which, as shown above, has the value of 103 + 18 = 121.

Hence the substance should have (in alkali) λ = 466 + 121 = 587. Observation gives λ 584. Nearly the same observation is given if chlorine, iodine, or methyl be taken in place of bromine, hence I use X in the formulae.

Consider now thymol-and carvacrolphthaleins. To calculate them they may be split into two

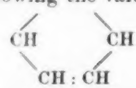


rings, plus the 121 tautomerism. X is methyl and Y isopropyl in the one case, and *vice versâ* in the other, but since all non-tautomeric groups have nearly the same value, the two substances have nearly the same colour. Taking the ortho X at 7 and the meta Y at 15 (as if it were meta-X), we have an addition of 22 to each ring; hence both substances should have spectra which are 44 units above that of phenolphthalein. Observed: Phenolphthalein λ 554, thymolphthalein λ 597, carvacrolphthalein λ 601. If we allow the meta-isopropyl group 16 instead of 15, the calculated gain on phenolphthalein will be 46, and 554 + 46 = 600, which agrees with the observation on carvacrolphthalein. The so-called sulphonephthaleins can also be calculated in the same way, giving the ortho-position in the tautomeric rings the value 7 and the meta-position 15, and allowing 27 for the group



outside the tautomerism, *e. g.* "bromphenol-purple," which has 4 orthobromines, should be (4 × 7) + 27 or 55 above dioxybenzhydrol = λ 596; observed λ 594.

All the naphthalene derivatives of the classes already discussed can be brought into the scheme by allowing the value 53 to the grouping



which when added to benzene turns it into naphthalene.

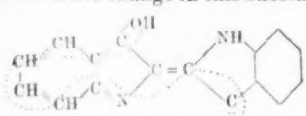
Thus phenol-α-naphtholphthalein is $554 + 53 = \lambda\ 607$ and α-naphtholphthalein is $607 + 53 = \lambda\ 662$. The tautomeric ring

has thus the value $219 + 53 = 272$ and the para-α-naphthylamine-ring the value 276. The grouping

when non-tautomeric is a combination of the C_4H_4 and the C_2H_2 loads and its value is therefore $53 + 22 = 75$.

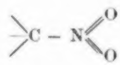
Colour of Indigo.

The most probable tautomeric change in this substance is as shown below:



This is CCO + CCC + CCC + CCN + CCN + CCO fully tautomerised, plus the load C_6H_4NH. Allowing 20 as an estimate from analogy for the latter the total is 610. This is evidently quite near the truth, but of course indigo cannot be observed in water solution, for which all the other data are calculated. Sulphindigotic acid in water has λ 614. It is next desirable to discuss the nitro and nitroso-colours, which do not at once fit into the scheme. Unfortunately all the published data deal with substances in alcoholic solution, consequently in the case of alkaline solutions the molecule contains non-ionised sodium or potassium, and in acid solution an acid radicle, thus introducing an unnecessary complication due to varying load on the molecule. The first thing that is noticed is that the spectrum of an alkaline nitro-phenol is frequently about 100 units above that of the parent substance, which certainly on my theory suggests that it has one tautomerism more in the alkaline condition than when free. Examples from Baly's and Tuck's work are *p*-nitrophenol λ 308, K-salt λ 405; *p*-nitrosophenol λ 311, Na-salt λ 415; *o*-nitrophenol λ 338, K-salt λ 435; *m*-nitrophenol λ 328, K-salt about λ 390, very broad, evidently imperfectly formed.

It is probable that the free substances have merely the tautomerism of phenol (λ about 300), viz. CCO + 2CCC, whereas the alkaline forms have the nitroic-acid tautomerism involving a new unit, viz. C – N = O in the nitroso-compounds and



in the nitro-compounds. This would afford an explanation in the case of the ortho-compounds, in which there would be four tautomerisms instead of three, viz. CCO – CCC – CCC – CNO, but in the para-compounds there would still be only three, yet the wave-length is only 30 less. This must remain an anomaly. If the cause of the colour of quinone itself (as well as azobenzene, benzil and other coloured substances incapable of tautomerism in the ordinary sense) were known, no doubt paranitrophenol could be correlated better with quinone than with a tautomeric sodium phenate (quinone having the very high λ 461), seeing that sodium para-nitrosophenol is almost certainly a salt of the oxime of quinone.

We come next to the difficult problem of the azo-dyes. Their bands are broad and indefinite, consequently measurements of their centres have no exactitude. The broadness of the bands means a very perturbed vibration or irregular periodic-time of the moving electron in its orbit, which renders the additive law almost inapplicable. In addition, the grouping C – N = N – C is not capable of ordinary tautomerism; hence, for example, in *p-p*-dioxyazobenzene the electron cannot travel from one end to the other as it does in dioxybenzhydrol. Nevertheless a few regularities can be traced. Tuck (J.C.S., 1909) has, for example, pointed out that alkaline oxyazobenzene and neutral aminoazobenzene have nearly the same spectrum, the figures being λ 420 and λ 424 respectively. This can be accounted for on my theory if the vibration in the group PhNNC is assigned the value 201, because the other part of the molecule is clearly tautomeric and has the value 219 for $C_6H_4O\diagup$ (and 223 for $C_6H_4NH_2$), these giving 420 and 424 on addition to the constant 201.

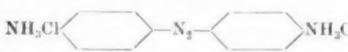
Again, the colour of *free* oxyazobenzene can be roughly calculated if it be assumed to be quinone-phenylhydrazone (the salt having, on the contrary, the azo-formation). The tautomerism would then be

Assuming by analogy, since the CCN tautomerism is five less than the CCC one, that the CNN tautomerism should have the value 93, we get CCO + CCC + CNN + 22 for half-ring + 16 for phenyl, adding up to 328 for the calculated absorption-band in water (Baly gives λ 332 [plus 455 faint] in alcohol). However, if this theory is the correct one, it follows logically that

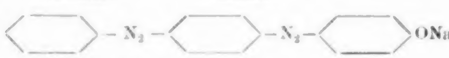
free aminoazobenzene is *not* quinone-iminephenylhydrazone, for in that case it would have λ 332 (328 + 223 − 219) instead of λ 424.

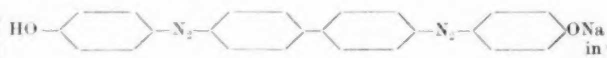
I have to confess that I have almost abandoned the hope of finding an explanation of the higher azo-dyes. For example, the following substances of widely different constitution have almost exactly the same absorption-band, and I hope that some other worker will attempt an explanation, now that the wave-lengths are available:

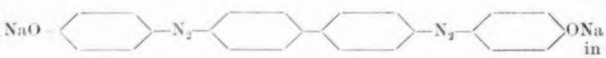
(*a*)  (acid water) λ 497.

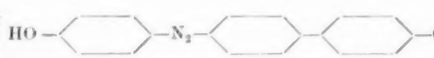
(*b*)  (acid water) λ 499,

(*c*)  (water) λ 494.

(*d*)  λ 497,

(*e*)  λ 496 in water + $NaHCO_3$.

 λ 370 in water + NaOH,

(*f*)  λ 492 in water + $NaHCO_3$,

 λ 470 in water + NaOH,

whilst the other symmetrical substance

has λ 515.

Substitution of a naphthalene- for a benzene-ring has a larger effect in the azo series than in the di- or tri-phenylcarbinol series. Thus alkaline benzeneazo-α-naphthol has its band about 85 units above that of benzene-azophenol, and the paranitro-derivatives (see Watson, *l. c.*, p. 89, v; and 91, xiii) have the bands at λλ 494 and 576 respectively.

Here, in conclusion, I may mention a most remarkable fact which some other worker may be able to explain, if it is not a mere coincidence, viz. that the bands of (*a*) phenolphthalein, (*b*) phenol-α-naphtholphthalein, and (*c*) (di) α-naphtholphthalein are almost exactly in the ratio 10 : 11 : 12, viz. λλ 554, 608 and 662,* and those of (*d*) nitrobenzeneazophenol and (*e*) nitrobenzeneazo-α-naphthol are exactly in the ratio 6 : 7, viz. 494 and 576. This certainly appears to be connected with units of tautomeric change also.

* The ratio agrees even better if 18 be subtracted from each for the $C_6H_4CO_2H$ group, giving benzhydrol derivatives.

MEDICAL FOLK-LORE OF THE ABANTU IN THE LIJDENBURG DISTRICT, TRANSVAAL.

By Cornelis Pijper.

In the great number of books that have been written on South African natives several data may be found concerning the way in which the witch-doctors treat their ailing fellow-men. Yet the following observations, made by me while I was practising in the Lijdenburg district, have, so far as I know, never been published before; they are to be regarded as a contribution to the study of comparative medical folk-lore.

(*a*) Inflammation of the eyes is combated by making holes in the lobes of the ears; I was given to understand that in this way the disease was given an opportunity to escape. It is interesting to note that this practice is met with in Europe too; in Holland the people improve on it by wearing rings in the holes.*

(*b*) Children who suffer from nocturnal incontinence of urine are made to eat a certain kind of mouse ("streepmuis"), roasted whole. (Zoology knows two kinds of "streepmuis" in the Transvaal: one with one stripe—*Dendromus mesomelas*; the other with four stripes—*Arvicanthus pumilio.*) It is interesting to compare Plinius, Hist. Natur., xxx, 14 (47)—"Urina infantium cohibetur muribus elixis in cibo datis," and Béal, Passetemps d'un practicien d'Auvergne, Paris, 1900—"Les bonnes femmes vous diront avec conviction, qu'une friture de rats empêche les mioches de pisser au lit." I have tried to find out what, in the native mind, was the "ratio" of this treatment, but have not met with success.

(*c*) For affections of the chest the native doctors like to administer the dejections of the hippopotamus, boiled. This highly-valued material is procured by means of barter from the natives living near the Limpopo; I am sorry that I have not been able to find out exactly what is given in exchange. The internal use of the dejections of animals (and even of man) was in former centuries, even as late as 1650 (see the description in the works of the Dutch poet Cats of that time), common all over Europe, while already Galenus is stated to have said: "Medicus ignorare non debet medendi

* Van Andel, Volksgeneeskunst in Nederland, 1909, p. 186.

rationem per stercora." (I have been unable to find where he said it.) I hope that some other observer may be able to find out why the natives only use the dejections of the hippopotamus.

(*d*) Burns and scalds are treated by the external application of poultry-dung; the white pieces are the best. It is interesting to note that van Andel (cited above) has (p. 395) the following quotation from the Wyse Jaerbeschryver (1663): "Koedreck, met goet melck vermenght op een doeck gesmeert en daer (de brandwond) opgelegt, treckt de hitte geweldigh uit" (cow-dung, well mixed with milk, applied [to the burns] on a piece of cloth draws the heat out as by magic). Even at the present day faeces of all kinds of animals, and even of human beings, are being extensively used in the treatment of all kinds of wounds by the people in Europe; and Cabanès and Barraud (Remèdes de bonne femme, Paris, 1907) prove by a quotation out of a Dictionnaire des sciences médicales (1812) that, in France at least, official medical science occasionally took refuge to it even then: "En quelques occasions on a cru appliquer avec succès quelques excréments comme la fiente humaine, celle de l'hirondelle, l'urine humaine, etc." For the present-day use of faeces in the medical folk-lore of the Boers in Transvaal I refer to my De Volksgeneeskunst in Transvaal, Leiden, 1919.

(*e*) Rubbing the gums with a bug is thought to facilitate the teething of children. Rubbing the gums with saliva or human milk is practised all over Europe*; of what use the bug is supposed to be escapes me altogether.

(*f*) Round the ankles of newly-born infants suffering from convulsions small pieces of cloth are tied, filled with a resinous substance, very much like asafoetida. It is difficult to grasp in what way an effect is expected. V. Andel, *op. cit.*, p. 224, relates how in some parts of Holland a small pouch, filled with asafoetida, is worn on the chest to ward off attacks of asthma; it is worth while to note that both convulsions and asthma come on and leave off suddenly. V. Andel regards this pouch to be an "amulet"; but as he omits to say what an "amulet" is supposed to be, and as works of reference do not bring us any further here, it is perhaps better to resign ourselves to our ignorance, at least for the present. It is interesting to note that, even at the present day, an alcoholic extract of asafoetida is being extensively prescribed for patients suffering from hysteria, so often complicated by sudden convulsions; and while according to some its effect is only dependent on the "suggestive" action of its smell and taste, others, and amongst those no less an authority than Lauder Brunton, maintain that it has a powerful effect on muscles (comp. Pinkhof and van der Wielen, Vademecum Pharmacotherapeuticum, Amsterdam, 1917, p. 65).

(*g*) In babies suffering from skin-rashes the treatment is not intended to make the rash disappear, but first of all to make it come out; for a

* V. Andel, *op. cit.*, p. 140.

similar belief in Germany I beg to refer to the article on skin diseases in Henoch, Vorlesungen über Kinderkrankheiten, Berlin, 1903.

(*h*) For skin disease washing with cow's urine is deemed to be the best treatment. We Europeans have to remember that this opinion was held in European, specially French, universities too not four centuries ago. I quote Dioscorides—"Sed vetus (urina) ulcera capitis manantia, furfures, psoras, fervidas eruptiones multo magis abstergit,"* and Albertus Magnus—"On doit être assuré, qu'il n'y a point de remède plus souverain au monde: car sans dire qu'elle guérit la teigne, les ulcères suppurans des oreilles et les places invétérées, elle sert encore á plusieurs autres maux et on ne voudrait pas pour beaucoup ne savoir sa valeur."† Pope John XXI, who before he became Pope had been a professor of surgery, recommended the urine of infants as an eye-wash, "experience having evidently shown that this fluid, which is usually bland and unirritating, a solution of salts of a specific gravity such that it would not set up osmotic processes in the eye, was empirically of value (James J. Walsh, Mediaeval Medicine, London, 1920, p. 152).

(*i*) For joints that have become stiff and fixed in abnormal positions the patient is given a decoction of frogs' legs: the inherent mobility of the frog's joints will pass on to those of the patient. It is well to remember that in some country districts of Holland suppurating, stiff joints are covered with "frogs'-butter"—unsalted butter wherein frogs have been suffocated and allowed to decompose (van Andel, *op. cit.*, p. 414); in Zwaben this remedy is applied to frost-bites (J. Jühling, Die Thiere in der deutschen Volksmedicin, Mittweida, 1900, p. 40).

* Pedanii Dioskoridis Anazarbei De Materia Medica Libri Sex. Parisiis, 1537, cap. lxxiii.

† Les admirables secrets d'Albert le Grand, p. 184.

ON A SPECIES OF MICRODON FLY (DIPTERA) FROM NATAL.

By S. H. Skaife, M.A., M.Sc.

(With Plate XIII.)

The genus *Microdon* (Syrphidae) is remarkable for the aberrant nature of the habits and structure of the larvae. The majority of the species included in this genus are rare and little known, and in the case of only very few of these species are the larval, pupal and adult forms known. The larvae, in the few cases known, are tolerated guests, or synoeketes, of ants, and are mollusc-like creatures, more or less hemispherical in shape, and move slowly along on the flattened ventral surface. Their relationship to their hosts has never been ascertained, but it seems probable that they are scavengers, like the larvae of the nearly allied genus *Volucella*.

Bezzi, in his Syrphidae of the Ethiopian Region (1915), lists twenty species of *Microdon* from Africa, and of these some half a dozen are recorded from South Africa. He provisionally subdivides the genus into six groups, and the species described in this paper comprises his Group I. In Bezzi's work this subdivision includes only the one species, *M. illucens*, Bezzi, from Mozambique, a species which was founded on a single badly mutilated specimen. Nothing was known of the immature stages when Bezzi published his description. The present paper consists of a description of these stages together with a complete description of the adult.

A nearly full-grown larva was found on March 3, 1920, in an old bag of *Acanthopsyche junodi*, Heylaerts, at Mountain Rise, near Pietermaritzburg. The bag had been long vacated by its original owner, and was occupied, when found, by a small colony of the little black Dolichoderine ant, *Technomyrmex albipes*, Smith, race *Foreli*, Emery,* the *Microdon* larva being a guest of these ants. The ants and their guest were placed in a small Petri dish, together with a little honey and water to serve as food for the ants. The larva moved slowly about the nest and seemed to be totally ignored by its hosts. It apparently took no food, and there was very little refuse present on which it could feed. At the end of ten days it ceased moving about and its skin darkened somewhat in colour. On March 16, 1920, two small, chitinous horns were seen to be protruding from the anterior portion of the larva's body, thus marking the commencement of the pupal stage. On April 8, 1920, the adult emerged, after a pupal stage of twenty-three days.

Description: Microdon illucens, Bezzi.

Larva.—5–6 mm. long × 3·5–4 mm. broad. Yellowish white in colour;

* Determined by Dr. G. Arnold.

no appearance of segmentation or of head. Covered on the dorsal region with a network of broken white lines made up of peculiar setae with flattened, stellate heads, with a narrow line, bare of setae, running longitudinally along the back; the border between the dorsal and ventral regions is armed with a narrow, inconspicuous fringe of peculiar, membranous hairs; there is also a white, beaded line of setae running round this border. The terminal stigmata are very prominent, almost contiguous, and situated on a prominence having a conspicuous white periphery, the stigmata surrounded by brown, strongly chitinised lips.

Puparium.—Exactly the same as the larva, except for the presence of two prominent chitinous horns about a third of a millimetre in length, deep brown in colour, and situated at the anterior end of the dorsal region. Dehiscence occurs transversely along a line just posterior to these horns, the puparial skin bursting irregularly into three triangular pieces, the adult emerging through the opening thus made; there is no ptilinum.

Adult.—Length of body 8 mm. Head wider than thorax, black, frons covered with conspicuous silvery pubescence, ocellar region bare; eyes fringed with silvery hairs; 1st joint of antennae longer than third, brown, 2nd joint short, terminal joint stout and blackish brown in colour. Thorax black, punctate, quadrate, thinly covered with a fine, greyish pubescence; a conspicuous band of golden-yellow hairs, broken in the middle, runs transversely across the thorax along the suture; a much less conspicuous band runs along the anterior border of the scutellum. Scutellum black, shining, rounded, armed with two small, curved, black spines. First segment of abdomen small, same width as the scutellum, black; 2nd elongated, constricted in the middle, black, with a narrow, yellow streak on each side, leaving in the centre a black median line broadening out anteriorly and posteriorly; remainder of abdomen black, with a greenish sheen in strong light, covered thinly with a fine, greyish pubescence; 4th segment longer than 3rd or 5th; two conspicuous bands of golden yellow hairs run along the hind border of the 3rd and of the 4th segments. Four front legs testaceous, with fuscous femora; hind femora black, proximal half of hind tibiae white, distal half blackish brown, tarsi testaceous. Wings hyaline, except for slight infuscations along some of the veins, middle cross-vein situated on the basal third of the discal cell, third longitudinal vein provided with the usual peculiar stump in the subapical cell.

One specimen, a female, lodged in the S.A. Museum, Cape Town.

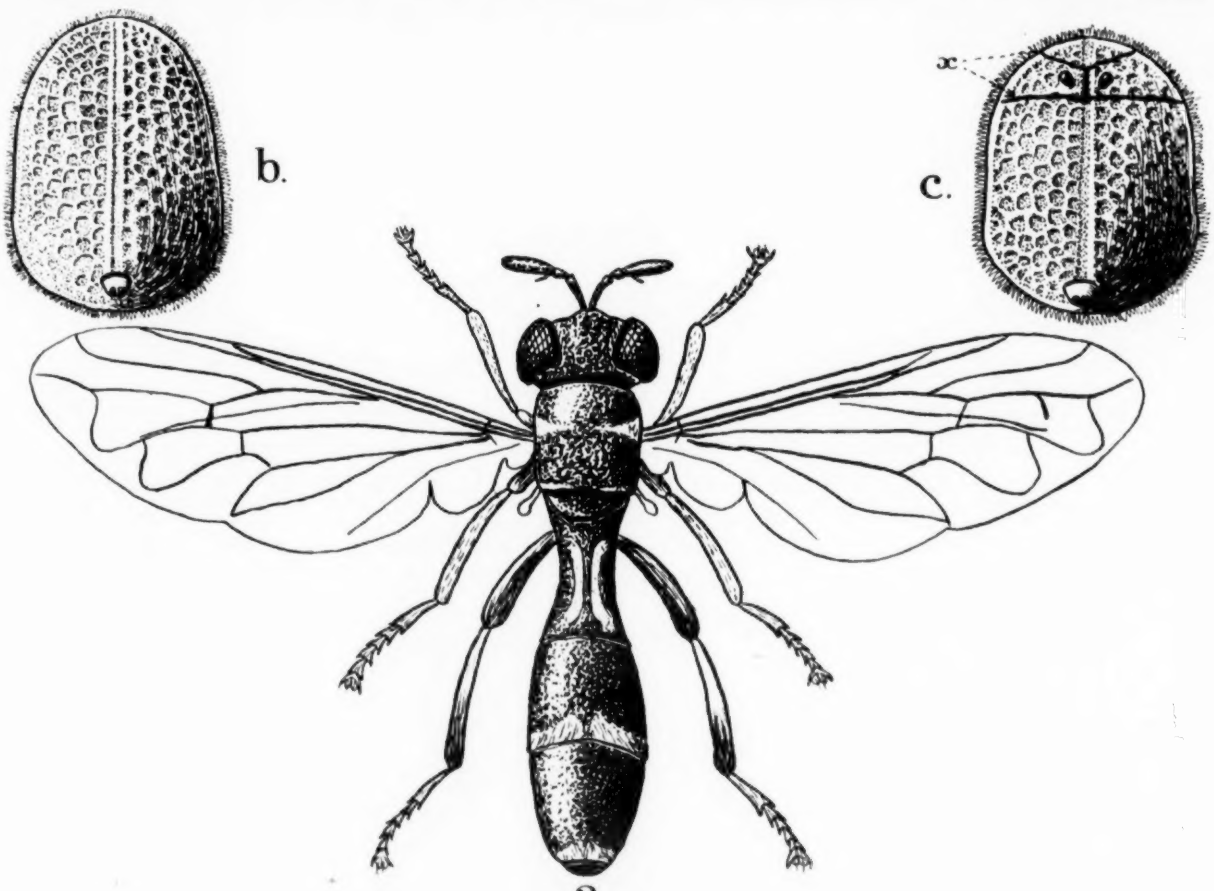
EXPLANATION OF PLATE XIII.

FIG.

a. *Microdon illucens*, Bezzi. ♀ × 10.

b. *Microdon illucens*, Bezzi. Larva. × 8.

c. *Microdon illucens*, Bezzi. Puparium, showing lines of dehiscence (*x*). × 8.



Microdon illucens, Bezzi.

Adlard & Son & West Newman, Ltd.

ON THE INTEGRATED VELOCITY EQUATIONS OF CHEMICAL REACTIONS.

By J. P. Dalton.

(From University College, Johannesburg.)

§ 1. A Certain Function and its Derivatives.

The object of this note is to show how the integrals of many velocity equations which occur in practice may be written down in terms of a certain function of the relative initial concentrations of the reactants, and of its derivatives. The function in question is

$$\psi(x) = \frac{1}{x-1} \log_e \frac{1-\frac{\lambda}{x}}{1-\lambda} \quad . \quad . \quad . \quad (1)$$

where λ is a parameter whose significance will shortly appear.

Successive derivatives of ψ according to x are given by the scheme

$$(x-1)\psi^r(x) + r\psi^{r-1}(x) = (-1)^{r-1}\,\overline{r-1}\,!\left[\frac{1}{(x-\lambda)^r} - \frac{1}{x^r}\right] \quad (2)$$

The function and its derivatives become indeterminate at $x = 1$, but definite limits exist as $x \rightarrow 1$; for these limits we find

$$\psi(1) \rightarrow \left[\frac{1}{1-\lambda} - 1\right] \quad . \quad . \quad . \quad . \quad (3)$$

and, in general,

$$\psi^{r-1}(1) \rightarrow (-1)^{r-1}\frac{\overline{r-1}\,!}{r}\left[(1-\lambda)^{-r} - 1\right] \quad . \quad . \quad (4)$$

ψ, ψ' and ψ'' are tabulated in § 5 for values of λ from 0·1 to 0·9, and for certain values of x over the range 1–10.

§ 2. The Occurrence of the Function ψ.

The velocity equation of a chemical reaction is a differential equation of the type

$$\frac{dx}{dt} = k(a-x)^\alpha (b-x)^\beta (c-x)^\gamma \ldots \quad . \quad . \quad . \quad (5)$$

where a, b, . . . are the initial molecular concentrations of the reactants; α,

β, . . . the numbers of molecules of each which take part in the reaction; x is the molecular amount transformed in time t, and k is the velocity constant of the reaction.

When investigating the influence of relative initial concentration on the course of a reaction, or when comparing the velocities of different reactions, it is advantageous to work in terms of a "modular time"—that is, the time which elapses before a specified fraction, λ, of the total transformation has taken place.*

Of the initial concentrations concerned, there must be at least one which is not greater than any of the others. Let one such be a. The reaction will be complete when $x = a$. Refer all concentrations to a as unit, and write $x = \lambda a$ so that λ is the fraction transformed at any stage; and, for the ratios b/a, c/a, . . . write n_1, n_2, . . . Equation (5) then becomes in modular form

$$\frac{d\lambda}{d\vartheta} = ka^{\alpha-1+\beta+\gamma+\cdots}(1-\lambda)^{\alpha}(n_1-\lambda)^{\beta}(n_2-\lambda)^{\gamma}\cdots \quad . \quad (6)$$

The integration of equation (6) can always be effected by elementary methods,† but if the indices α, β, . . . are greater than 3 the process becomes laborious. Indeed, the chemist apparently prefers to choose, when possible, $n_1, n_2, \ldots = 1$, so as to obtain a more tractable equation. That procedure, however, has the disadvantage of obscuring the effects of the influence of the relative initial concentrations of the reactants upon the course of the reaction. It may, perhaps, be of utility to show how the integrals of some of the commoner types of reaction may be obtained immediately as special cases of a general formula.

If there are p reactants in all, and if only one molecule of each reactant is concerned, equation (6) becomes

$$\frac{d\lambda}{(1-\lambda)(n_1-\lambda)\ldots(n_{p-1}-\lambda)} = ka^{p-1}d\vartheta \quad . \quad . \quad (7)$$

where a is the lowest initial concentration involved. The result of integrating (7) in the usual way may be written

$$\sum_{i=0}^{i=p-1} \frac{\log \dfrac{n_i}{n_i-\lambda}}{\prod\limits_{j=0}^{j=p-1}(n_j-n_i)} = ka^{p-1}\vartheta \quad . \quad . \quad (8)$$

Now

$$\sum_{i=0}^{i=p-1} \frac{1}{\prod\limits_{j=0}^{j=p-1}(n_j-n_i)} = 0 \quad . \quad . \quad . \quad (9)$$

* *Cf.* Todd, Phil. Mag. xxxv, p. 281 (1918).

† See, *e. g.*, Todhunter, Integral Calculus, Ch. II.

and n_0 is unity (the lowest initial concentration), hence we find

$$\sum_{i=1}^{i=p-1} \frac{\dfrac{1}{n_i - 1} \log \dfrac{1 - \dfrac{\lambda}{n_i}}{1 - \lambda}}{\prod\limits_{j=1}^{j=p-1} (n_j - n_i)} = ka^{p-1}\vartheta \quad . \quad . \quad (10)$$

or, in terms of the function suggested in § 1,

$$\sum_{i=1}^{i=p-1} \frac{\psi(n_i)}{\prod\limits_{j=1}^{j=p-1} (n_j - n_i)} = ka^{p-1}\vartheta \quad . \quad . \quad (11)^*$$

So that, for instance, the integrated equation for a quadri-molecular reaction in which one molecule of each reactant takes part, becomes

$$\frac{\psi(n_1)}{(n_2 - n_1)(n_3 - n_1)} + \frac{\psi(n_2)}{(n_1 - n_2)(n_3 - n_2)} + \frac{\psi(n_3)}{(n_1 - n_3)(n_2 - n_3)} = ka^3\vartheta \quad (12)$$

If a, b, c, d, are the initial concentrations, the substitutions $n_1 a = b$, $n_2 a = c$, $n_3 a = d$, $\lambda a = x$, $\vartheta = t$, reduce this to the form of integral given in the text-books.

§ 3. The Case of Multiple Poles.

When the initial concentrations of two or more reactants are equal, or when the number of molecules of any reactant exceeds unity, the corresponding integral could be obtained from a consideration of the appropriate limit in equation (11). This, though interesting mathematically, is hardly to be recommended as a practical method for chemists. It seems preferable to consider separately the different types according to the number of different concentrations involved in the integrand.

(a) *Single term denominator.*

This reduces to the comparatively trivial case of all initial concentrations being equal. If the reaction is N-molecular the differential equation is

$$\frac{d\lambda}{(1-\lambda)^N} = ka^{N-1}d\vartheta \quad . \quad . \quad . \quad . \quad (13)$$

and the integral may be written

$$(-1)^{N-2} \frac{1}{N-2!} \psi^{N-2}(1) = a^{N-1}k\vartheta \quad . \quad . \quad (14)$$

or

$$\frac{1}{N-1}\left[(1-\lambda)^{1-N} - 1\right] = a^{N-1}k\vartheta \quad . \quad . \quad (15)$$

which is obtainable by direct integration.

* The vanishing factor for $j = i$ is, of course, excluded from Π.

(b) *Two-term denominator.*

The type of integrand in this case is

$$\frac{1}{(1-\lambda)^{a}\,(n-\lambda)^{\beta}}.$$

It is resolved into

$$\sum_{1}^{a} \frac{A_r}{(1-\lambda)^r} + \sum_{1}^{\beta} \frac{B_r}{(n-\lambda)^r}$$

where

$$A_r = (-1)^{\beta}\ {}^{\beta+a-r-1}C_{a-r}\ \frac{1}{(1-n)^{\beta+a-r}} \quad . \quad . \quad (16)$$

$$B_r = (-1)^{a}\ {}^{a+\beta-r-1}C_{\beta-r}\ \frac{1}{(n-1)^{a+\beta-r}} \quad . \quad . \quad (17)$$

The C's are the usual binomial coefficients. Write $a + \beta = N$ (the total number of molecules involved), and the integral becomes

$$\begin{aligned} ka^{N-1}\vartheta = (-1)^{a} &\sum_{1}^{a-1} \frac{1}{(n-1)^{N-r-1}}\ {}^{N-r-2}C_{\beta-1}\ \frac{\psi^{r-1}(1)}{r-1\,!} \\ &+ \sum_{1}^{\beta-1} \frac{(-1)^{r+a}}{(n-1)^{N-r-1}}\ {}^{N-r-2}C_{\beta-r}\ \frac{\psi^{r-1}(n)}{r-1\,!} \\ &+ (-1)^{N} \frac{1}{(n-1)^{a-1}} \frac{\psi^{\beta-1}(n)}{\beta-1\,!} \quad . \quad . \quad . \quad . \quad (18) \end{aligned}$$

This holds for $a > 1, \beta > 1$. If $a > 2$ the last term in (18) may be dropped, and the second summation carried out between the limits 1 and β.

One can well imagine that the form of the solution (18) may not appeal to those for whom it is intended; but its generality will make it worth while mastering its symbols. It embraces, for instance, all the equations discussed by Todd,* which he integrates individually, and for which he gives individual curves.

As an example of the application of (18) consider the equation

$$\frac{dx}{dt} = k(a-x)^3\,(b-x)$$

Here $a = 3$, $\beta = 1$, $N = 4$. Substitution of these values in (18) gives

$$ka^3\vartheta = \frac{1}{(n-1)^2}\Big[-\psi(1)-(n-1)\psi'(1) + \psi(n)\Big] \quad . \quad (19)$$

And for the equation

$$\frac{dx}{dt} = k(a-x)^2\,(b-x)^2$$

where $a = 2$, $\beta = 2$, $N = 4$, we get

$$ka^3\vartheta = \frac{1}{(n-1)^2}\Big[\psi(1) - \psi(n) + (n-1)\psi'(n)\Big] \quad . \quad (20)$$

Substitution of the equivalents given in § 1 leads to the ordinary algebraical solutions; while the use of the tables in § 5 gives appropriate numerical results.

* *Loc. cit.*

It may be worth while pointing out some special simplifications of (18) that occur in practice.

$\alpha = 1$ the two summations fall away, leaving

$$k a^{\beta} \vartheta = (-1)^{\beta-1} \frac{1}{\beta-1\,!} \psi^{\beta-1}(n) \quad . \quad . \quad . \quad (21)$$

If $\alpha = 2$ the integral may be written

$$k a^{\beta+1} \vartheta = \frac{1}{(n-1)^{\beta}} \Big[\psi(1) - \psi(n) - (1-n)\psi'(n) - \ldots - \frac{(1-n)^{\beta-1}}{\beta-1\,!} \psi^{\beta-1}(n) \Big] \quad . \quad . \quad . \quad . \quad (22)$$

If $\beta = 1$ we get

$$k a^{\alpha} \vartheta = (-1)^{\alpha+1} \frac{1}{(n-1)^{\alpha-1}} \Big[\psi(n) - \psi(1) - (n-1)\psi'(1) - \ldots - \frac{(n-1)^{\alpha-2}}{\alpha-2\,!} \psi^{\alpha-2}(1) \Big] \quad . \quad . \quad . \quad . \quad (23)$$

§ 4. The Determination of the Molecular Order.

The results already given seem sufficient for the determination of molecular order with a minimum of experimental labour. Suppose, for instance, three reactants, A, B and C, are involved. The total number, N, of molecules, taking part may be determined in the usual way by performing two different experiments with all reactants in the same initial concentration, say a_1 and a_2. Then from (14),

$$(-1)^{N-2} \frac{\psi^{N-2}(1)}{N-2\,!} = k a_1^{N-1} \vartheta_1 = k a_2^{N-1} \vartheta_2 \quad . \quad . \quad (24)$$

The same fraction, λ, must be transformed in each case. These determine N and k. Now repeat the experiment with two concentrations, say those of B and C, initially equal, and the other lower, the ratio being n. Suppose N has been found to be 5. Of A, either one, or two, or three molecules must be involved. The appropriate solutions would be

$$k a^4 \vartheta = -\frac{1}{3\,!} \psi'''(n) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

$$k a^4 \vartheta = \frac{1}{(n-1)^3} \Big[\psi(1) - \psi(n) - (1-n)\psi'(n) - \frac{(1-n)^2}{2\,!} \psi''(n) \Big] \quad (26)$$

and

$$k a^4 \vartheta = \frac{1}{(n-1)^3} \Big[2\{\psi(n) - \psi(1)\} - (n-1)\{\psi'(1) + \psi'(n)\} \Big] \quad . \quad (27)$$

Knowing k, a, ϑ and n, a little arithmetic will show which of these equations is satisfied, and thus determine the molecular order of A. If purely chemical considerations do not fix the orders of B and C, another reaction would have to be timed, using A and C in initially equal concentrations, and B lower. The same process would then give the molecular order of B.

§ 5. Numerical Values of ψ, ψ', ψ''.

$\psi\ (n)$.

n \ λ =	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
1	0·11111	0·25000	0·42857	0·66667	1·00000	1·50000	2·33333	4·00000	9·00000
2	0·05407	0·11778	0·19416	0·28768	0·40546	0·55962	0·77319	1·09861	1·70475
3	0·03573	0·07708	0·12566	0·18386	0·25541	0·34658	0·46914	0·64965	0·97291
4	0·02502	0·05728	0·09290	0·13515	0·18654	0·25126	0·33720	0·46210	0·68256
5	0·02129	0·04558	0·07370	0·10686	0·14695	0·19711	0·26329	0·35877	0·52603
6	0·01771	0·03785	0·06108	0·08837	0·12123	0·16219	0·21598	0·29327	0·42801
8	0·01325	0·02826	0·04549	0·06565	0·08980	0·11976	0·15891	0·21487	0·31189
10	0·01059	0·02254	0·03625	0·05222	0·07132	0·09494	0·12571	0·16956	0·24536

$\psi'\ (n)$.

n \ λ =	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
1	0·11728	0·28125	0·52041	0·86389	1·50000	2·6250	5·0556	12·000	49·50
2	0·02775	0·06222	0·10592	0·16268	0·23879	0·34543	0·50396	0·76528	1·2957
3	0·01212	0·02664	0·04431	0·06629	0·09437	0·13162	0·18385	0·26422	0·41503
4	0·00620	0·01471	0·02421	0·03579	0·05028	0·06905	0·09472	0·13320	0·19666
5	0·00430	0·00931	0·01523	0·02237	0·03118	0·04246	0·05768	0·08017	0·12053
6	0·00298	0·00642	0·01046	0·01529	0·02122	0·02873	0·03879	0·05353	0·07972
8	0·00167	0·00358	0·00580	0·00844	0·01164	0·01566	0·02099	0·02871	0·04229
10	0·00106	0·00228	0·00368	0·00534	0·00734	0·00984	0·01313	0·01787	0·02616

$\psi''\ (n)$.

n \ λ =	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
1	0·24783	0·63541	1·2770	2·4197	4·6667	9·7500	24·025	82·667	666·
2	0·02849	0·06580	0·11582	0·18473	0·28314	0·43066	0·66620	1·08612	2·01487
3	0·00822	0·01842	0·03128	0·04788	0·06993	0·10037	0·14489	0·21647	0·35721
4	0·00305	0·00756	0·01262	0·01897	0·02714	0·03803	0·05337	0·07708	0·11725
5	0·00174	0·00380	0·00630	0·00937	0·01324	0·01832	0·02532	0·03591	0·05539
6	0·00100	0·00218	0·00358	0·00529	0·00743	0·01019	0·01395	0·01957	0·02975
8	0·00042	0·00091	0·00148	0·00217	0·00302	0·00409	0·00555	0·00768	0·01148
10	0·00021	0·00046	0·00075	0·00109	0·00151	0·00204	0·00274	0·00377	0·00558

A REVISION OF THE SOUTH AFRICAN *AGAMAS* ALLIED TO *AGAMA HISPIDA* AND *A. ATRA*.

By G. A. Boulenger and J. H. Power.

(With three Text-figures.)

Introduction.

No group of South African reptiles stood more in need of revision than the forms of the genus *Agama* that cluster round *A. hispida* and *A. atra*. This has been felt not only by us but by all whose task it has been to name specimens. The account in the British Museum Catalogue of Lizards, based on a very small series of specimens, has long ceased to fulfil its purpose, and the senior author had on various occasions endeavoured to improve the unsatisfactory state of things, but with little success, until we decided to join forces, in order, with the help of a very large material, to arrive at conclusions which would better stand the test of time.

If we have not succeeded in drawing up definitions which will in every case enable the student to determine without hesitation any isolated example that may fall into his hands—although we hope and trust such failures will be rare—we feel sure this is not due to any want of care on our part, but to the state of things in Nature, which precludes such rigid diagnoses as those less versed in the difficulties of systematics expect to find in the writings on which they rely to guide them. It must have occurred to any one of a critical turn of mind, on referring to works of descriptive zoology or botany, that even the best descriptions of the commonest species, when put to the test of a very large material, rarely cover the whole range of individual variation, exceptional deviations from the normal having usually been passed over, and it is clear that the precision of the definitions stands at an inverse ratio to the number of specimens conscientiously examined by the authors. This fault we have endeavoured by every means to avoid, and the result of our attempts from the standpoint of diagnostic rigidity has suffered in consequence. But we must rejoice rather than lament over these difficulties if they bring us nearer to truth. At any rate the work we have undertaken has been for us another lesson in the theory of evolution, and we recommend similar investigations to those who might still entertain doubts as to the derivation of species.

Before proceeding with the exposition of our work and summing up its results, it may be of retrospective interest to show how matters appeared to

stand when we started. The following synopsis has been drawn up by the senior author, from the material then available to him in the British Museum, as a basis for discussion and criticism on the part of his junior, who, though less favourably situated to deal with the historical aspect of the question, enjoyed the superiority of having access to much larger collections,* and was thus in a better position to judge of the constancy of the characters selected for the distinction of species and varieties. It will be seen further on how far this first tentative scheme of classification reflected the true state of things in Nature.

Synopsis of the Species (1916).

I. Dorso-lateral scales with the keels pointing obliquely inwards (towards the vertebral line); 70 to 115 scales round middle of body.

A. Upper parts very rough with enlarged spinose scales; a low crest or serration along the middle of the back, at least indicated by a regular series of strongly keeled scales (exceptionally interrupted); scales on upper surface of tibia unequal in size; fifth toe only exceptionally extending as far as first; tail not compressed, not crested, as a rule shorter than head and body in females.

Diameter of ear-opening much less than cleft of closed eye; third toe longer than fourth; ventral scales more or less keeled, usually strongly mucronate . . . . *A. hispida*, L.

Diameter of ear-opening much less than cleft of closed eye; third and fourth toes equal, or fourth slightly the longer; ventral scales smooth or feebly keeled . . . . *A. brachyura*, Blgr.

Diameter of ear-opening equal to or a little less than cleft of closed eye; third toe longest (exceptionally third and fourth equal); ventral scales smooth or feebly keeled . . . . . *A. distanti*, Blgr.

B. Upper parts not so rough, the enlarged scales forming more or less regular longitudinal series; a low crest or serration on the middle of the back, as in the preceding; scales on upper surface of tibia equal or nearly so; toes more slender, fifth extending as far as first, third and fourth equal or either slightly the longer; tail not compressed, not crested, longer than head and body in both sexes.

Head a little longer than broad: ventral scales more or less strongly keeled and mucronate . . . . *A. armata*, Peters.

Head as long as broad; ventral scales smooth or faintly keeled *A aculeata*, Merr.

C. Enlarged dorsal scales few or very irregularly scattered; scales on upper surface of tibia equal; fifth toe extending as far as first, third extending

* The collection in the British Museum contained only 37 specimens in 1885; in 1916, when we started work in collaboration, the number had risen to 232. In addition to these we had at our disposal the collections of the various South African museums, making up a very extensive series. It may be mentioned here that we have tabulated only those specimens which we considered sexually mature. These numbered some 757, but this number by no means represents the vast amount of material that we have examined. We beg to express our grateful thanks to the Directors of the various museums for their kindness in putting the material under their charge at our disposal.

beyond fourth ; tail longer than head and body, feebly compressed and crested in the male.

A vertebral crest or regular series of strongly keeled scales on the back; foot much shorter than tibia ; ventral scales more or less distinctly keeled . . . . *A. anchietae*, Bocage.

No trace of vertebral crest on the back ; foot as long as or slightly shorter than tibia ; ventral scales smooth . . . . . *A. methueni*, sp. n.

II. Dorso-lateral scales with the keels pointing obliquely outwards ; no dorsal crest ; ventral scales smooth ; ear-opening large ; fifth toe extending as far as first, or farther, third and fourth equal or either slightly the longer ; tail longer than head and body, more or less compressed and crested in the male . . . . . *A. atra*, Daud.

Enlarged dorsal scales usually present but small and few ; 105 to 150 scales round middle of body . . . . Forma *typica*.

No enlarged dorsal scales ; 150 to 160 scales round middle of body var. *microterolepis*, Blgr.

Scattered strongly keeled and mucronate scales on the back ; 170 to 180 scales round middle of body . . . . . var. *holubi*, Bocage.

Numerous strongly enlarged spinose scales on the back ; 90 to 110 scales round middle of body . . . . var. *rudis*, n.

As the work of testing and criticizing proceeded it was found that the definitions of divisoins I and II of the Synopsis deserved to stand, the direction of the dorso-lateral scales – a character which had not been pointed out before—being readily applicable in all cases. But many of the characters suggested for further subdivision proved to be either utterly worthless, or else subject to such frequent exceptions as to require a complete re-casting of the key. Thus the size of the ear-opening as compared to that of the eye-cleft was found to suffer exceptions amounting to 20 per cent. in *A. distanti* ; the degree of slenderness of the toes and the proportions of them varies much more than was supposed, and the same may be said of the scaling on the back, on the tibia, and on the belly.

The following detailed table was constructed to show the amount of variation in specimens from a given locality, collected in this case from the neighbourhood of Kimberley by the junior author.

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Kimberley	♂	81	4	3	×	3rd and 4th	×	20	20	21	A	×	×
„	♂	98	4	3	N	4th	×	21	21	23	A	×	×
„	♀	110	4	4	0	3rd	×	22	23	23	D	×	0
„	♀	102	4	3	N	3rd and 4th on left foot, 4th on the right foot	×	21	21	22	D	0	×
„	♂	104	4	4	×	3rd and 4th on right foot, 4th on left foot	0	23	24	24	N	0	×
„	♂	106	5	3	0	3rd and 4th	×	20	23	21	N	0	×
„	♀	93	3·5	3·5	N	3rd	×	20	20	20	D	×	×
„	♀	98	4	4	0	4th	0	22	22	23	D	0	0
„	♂	100	4	4	0	4th	×	22	22	23	N	0	0
„	♂	106	4	3	×	4th	×	24	24	25	A	0	0

EXPLANATION OF TABLE.

1. Length of body from snout to vent (in millimetres). 2. Length of cleft of closed eye. 3. Diameter of ear-opening. 4. Toes (long and slender × ; short and thick 0). 5. Longest toe. 6. Fifth toe extending as far as the first × ; fifth not extending as far as the first 0. 7. Length of tibia. 8. Length of head. 9. Length of foot. 10. Dorsal scaling (A = like *armata*, D = *distanti*, N = normal.). 11. Ventral scaling (keeled × ; smooth 0). 12. Scales on upper surface of tibia (equal × ; unequal 0).

Yet most of the differences pointed out in the above synopsis are not to be wholly discarded, as they apply to the *ensemble* of the lizards when numbers from one district or locality are brought together, and most of them may still be used, in combination, to define varieties, although each lacking that amount of fixity which would be required to justify specific distinction in the case of *A. brachyura, distanti, aculeata* and *armata*. It also became evident that the separation of *A. microterolepis* from *A. atra*, even as a variety, could not be upheld.

Before going further it may be well to explain how we understand the conception of species and varieties.

It is the opinion of the senior author that species are natural entities, of which, however, we can only convince ourselves in each case by an appeal to ethology and ontogeny.* He therefore regards the species in the Linnean sense as the real unit of classification. Species may be defined as groups morphologically and physiologically limited and stable at the present day. From the physiological standpoint we need not fear to include under one species forms which show an enormous range of morphological variation. So we regard man, the dog, the horse as each representing one species, although the different forms included under each differ more from each other than do many that have proved to be fully entitled to specific rank. It is a common fallacy to fancy that such enormous variations occur only in domesticated species; many examples of the contrary could be adduced in the case of Reptiles and Batrachians, such as the wall-lizards of Southern Europe, the edible frog, etc. There is no measure for specific characters: in every case we have to consult Nature, rigid rules cannot be laid down.

In the case of the European Batrachian fauna, which has been better studied from the point of view of ethology and ontogeny than any other department of Herpetology, there should be no difficulty in deciding as to

* As opinions still differ on this "physiological sanction" of species we may quote Bateson's latest view (1914): "Whether science will hereafter discover that certain groups can by peculiarities in their genetic physiology be declared to have a prerogative quality, justifying their recognition as species in the old sense, and that the differences of others are of such a subordinate degree that they may in contrast be termined varieties, further genetic research alone can show. I myself anticipate that such a discovery will be made, but I cannot defend the opinion with positive conviction."

what constitutes a species. Thus the forms that cluster round *Rana temporaria*, although so difficult to distinguish that only an expert with considerable experience is able to do so without hesitation, are true species, whilst the forms of *Rana esculenta*, so different from one another that they have been referred to distinct genera by herpetologists of repute, can only be looked upon as varieties.*

It goes without saying that when the cabinet naturalist has to decide on what is a species, his opinion is merely provisional and based on experience derived from better-known forms, absence of connecting links in the material before him, and so on. But it is a safe rule not to accord the rank of species to forms that cannot be rigidly diagnosed; it is better, in the interest of science, not to overburden the system with specific names when we can have recourse to the simple method of registering forms of doubtful rank as varieties, often called subspecies.

The objection to the term *subspecies*, and as a consequence trinomial nomenclature, is this: that it is an absolutely unnecessary departure from the system established by Linnaeus, and that it ultimately results in such barbarisms as *Martes martes martes*, *Pica pica pica*, *Bufo bufo bufo*, etc., which find favour with so many among the latest systematists. The term "subspecies" dates back about 65 years. It was first introduced in zoology by the ornithologist Ludwig Brehm (1855), in botany by Hewitt Watson (1859). It is practically synonymous with the *variety* of Linnaeus. "Variety" has often been used in a loose sense, or to express various forms of variation, individual departures not sufficiently fixed, except by human artifice, and Latin names should not be bestowed on them save for the convenience of breeders and horticulturists. Linnaeus designated the varieties which he recognised by the letters of the Greek alphabet. He made a distinction between those forms which he regarded as derived from the species and those which, in his opinion, constituted *ex æquo* the concept of the species. For the former he began the series of varieties by the letter β, the *forma typica* being designated under the binomial, to the definition of which the varieties were simply tacked on; for the latter the specific diagnosis embraced the characters common to all the forms, and the varieties, being regarded as equivalent components of the species, were lettered α, β, γ, etc. He thus distinguished between derivative varieties and varieties constituting

* "Any herpetologist having before him the Japanese and Spanish frogs (*R. esculenta*), without any knowledge of the intermediate forms, would unhesitatingly pronounce them as representing distinct species. But if we pursue our investigations over the whole area occupied by this frog, viz. the whole of the Palaearctic region, we soon find all the differences by which we were at first struck to blend through such a number of intermediate forms as to leave no other course open but to maintain intact the Linnean species" (Boulenger, P. Z. S., 1891, p. 394). These remarks apply equally well to the Agamas now grouped under *A. hispida*.

together *collective species.* The plan followed by the senior author is to bestow the term *forma typica* on the earliest-described form of these "collective species," and that of *varietates* on those described later—a necessary concession to the rule of priority in nomenclature, which does not affect the philosophical side of the question, since it is mitigated by the practice of placing the typical form not necessarily at the head of the series, but in any position which expresses the relationship. Thus the forms of *Rana esculenta* are arranged in the following order*:

1. *Rana esculenta*, var. *ridibunda*, Pall.
2. „ „ var. *saharica*, Blgr.
3. „ „ *f. typica*.
4. „ „ var. *lessonae*, Camer.
5. „ „ var. *chinensis*, Osb.

In the case of *Agama hispida* the typical form would appear last on the list.

The general practice among systematists is to call subspecies or varieties forms which, however distinct, are known to intergrade. Intergrading is of two kinds:

It may be associated with the known joining of the two respective habitats, intermediate specimens inhabiting intermediate districts. Or the two habitats do not join, but an examination of a series of specimens will show an intergradation of characters; the forms are not strictly geographical.

Then, other systematists accord only subspecific rank to forms which, though not actually intergrading, differ too slightly from the type to be regarded as species; they do this, to some extent, on the assumption that, though not known to intergrade, they will be found to do so when larger series are examined. The describer's knowledge of the group to which the animal or plant belongs justifies him in anticipating the evidence of actual intergradation.

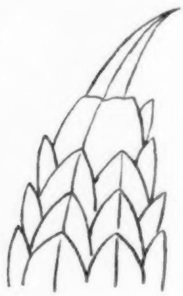
Several modern authors wish to restrict the subspecies to geographical forms. Any ever so slight deviation from the normal, if associated with a distinct habitat, becomes a subspecific form, for which the term *forma vicaria* has also been proposed. It seems, however, that it is just in such cases that the adjunction of a third name is least wanted, as the indication of the locality after the name of the species is amply sufficient to avoid confusion.

A considerable degree of differentiation is needed to justify even a varietal name, and we should be careful not to overburden nomenclature with Latin names; but when once it is ascertained that strong modifications affect a large proportion of the individuals from a given district, it is advisable to express the fact by a name, all the more if the individuals in

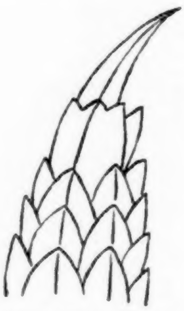
* *Cf.* Boulenger, Ann. Mag. N.H. (9), ii, 1918, p. 241.

As mentioned on the opposite page, we have arranged the species and varieties, as we now understand them, into three main groups which seem to express their natural affinities.

The three groups to which we allude are based on the direction of the dorso-lateral scales, inwards in I and II, outwards in III; and on the condition of the toes, as shown by the following figures:



GROUP I.



GROUPS II AND III.

In Group I the terminal dorsal scale of the third or fourth toe is not, or at most little, longer than the penultimate, and the ventral series, on the same toe, varying from 12 to 20 in number, rarely show black or dark-brown pigment at the end of the spinose keels. In Groups II and III the terminal dorsal scale is larger and the keels on the subdigital scales, 13 to 22 in number, are usually tipped with dark brown or black.

[*To face p.* 235.

question are not strictly geographical forms, and as from the fact that the characters on which the varieties are based are not constant, it will be optional to use the varietal name when it is required for the purpose of greater precision, or to drop it when the intermingling of forms is so complete as to render the distinction impracticable and hence worse than useless. And so we have dealt with the variation of *Agama hispida* in the wide sense, this lizard affording an excellent example of what we understand by the term "variety" as opposed to "species," and also of the difficulties with which the systematist is confronted in the case of polymorphic species.

There is also the question to consider whether the different varieties when they meet in one district do not cross, and thus give rise to individuals which further add to the perplexity of the student. It is, indeed, highly probable that such hybrids, or rather mongrels, do occur in the Agamas, but we have no means of satisfying ourselves that they are such, and it would be unscientific to get over the difficulties by suggestions which do not rest on any observed fact.

After long study, extending over three years, and embracing a very large material, we have agreed to divide the group of Agamas of which we undertook the revision into three species only: *A. hispida*, L., *A. anchietae*, Bocage, and *A. atra*, Daud., each of which includes a number of forms which cannot be defined with sufficient precision to justify specific rank, and which we therefore call varieties.

Synopsis of the Species.

I. Terminal dorsal scale on the third or fourth toe not, or but little, longer than the penultimate; dorso-lateral scales with the keels pointing obliquely inwards (towards the vertebral line) . 1. *A. hispida*, L.

II. Terminal dorsal scale on the third or fourth toe much longer than the penultimate; dorso-lateral scales with the keels pointing obliquely inwards . . . . 2. *A. anchietae*, Bocage

III. Terminal dorsal scale on the third or fourth toe much longer than the penultimate; dorso-lateral scales with the keels pointing obliquely outwards . . . . 3. *A. atra*, Daud.

It will be noticed that the characters on which the definition of the species now rests are just such as have entirely escaped attention on the part of previous writers.

A. hispida.—Five forms: *f. typica*, vars. *armata*, Peters, *aculeata*, Merr., *distanti*, Blgr., *brachyura*, Blgr.

A. anchietae.—Three forms: *f. typica*, var. *methueni*, Blgr. & Power, var. *n. knobeli*, Blgr. & Power.

A. atra.—Three forms: *f. typica*, var. *holubi*, Bocage, var. *rudis*, Blgr. & Power.

After each of these forms had been described from the limited material

at the disposal of the senior author, the specimens in various South African museums have been critically alluded to by the junior author, who is alone responsible for their identification.

1. Agama hispida, L.

a. *Forma typica.*

Lacerta hispida, Linn. Mus. Ad. Fred. p. 44 (1754), and Syst. Nat. (ed. 10) i, p. 206 (1755).

Agama spinosa (non Gray), Dum. & Bibr. Erp. Gén. iv, p. 502 (1837).

Agama hispida, Bouleng. Cat. Liz. i, p. 349 (1885).

The type of this species is not in existence.* There can, however, be no doubt as to the correct application of the name *hispida*, which was based by Linnaeus on figures in Seba's Thesaurus, vol. i :

P. 134, pl. 83, figs. 1, 2. *Lacertus, orbicularis, spinosus, sive Tapayaxin, ex Nova Hispania.* Hernandez, ix.

P. 173, pl. 109, fig. 6. *Bufo americanus, spinosus, Tapayaxin.*

Now, these quotations from Hernandez refer to a totally different lizard from Mexico, which bears the name *Phrynosoma orbiculare*, L. The figures given by Seba represent a stout *Agama*, no doubt from the Cape, like the other South African reptiles known in those early days, and the ventral aspect, in pl. 83, fig. 2, shows a dark, wide-meshed network on the body. *Lacerta hispida* is therefore the *Agama* which occurs in the neighbourhood of Cape Town. The following description is taken from specimens, preserved in the British Museum, which may be regarded as typical of that species.

Form.—Habit very stout, body much depressed. Head short, convex, subcordiform, its width equal to or greater than its length to occiput; snout very short, rounded; canthus rostralis very short; nostril directed outwards, in a convex but not tubular shield, which, exceptionally, may be nearly flat, pierced below the canthus rostralis; length of head 4 (male) to $4\frac{1}{2}$ (female) times in length to vent. Diameter of ear-opening much less ($\frac{1}{2}$ to $\frac{3}{4}$) than cleft of closed eye. Limbs moderately elongate; the hind limb, pressed against the body, reaches the shoulder or the neck; length of hand equal to depth of head; fingers short, third longest; tibia or crus as long as or a little shorter than the head or the foot; toes short, third longer than fourth, fifth not extending as far as the first, than which it is not or but slightly longer. Tail cylindrical, rather slender, a little longer or a little shorter than head and body ($\frac{6}{7}$ to $1\frac{1}{3}$ times in males, $\frac{3}{4}$ to $1\frac{1}{10}$ times in females).

Measurements (in millimetres) :

* *Cf.* Andersson, Bih. Sv. Vet.-Ak. Handl., xxvi, iv, 1, 1900, p. 11.

	1.	2.	3.	4.
From snout to vent	88	67	100	92
Head (to occiput)	23	16	24	22
Width of head	24	18	24	23
Depth of head	16	12	16	15
Diameter of eye-cleft (eye closed)	4	3·5	5	5
„ „ ear-opening	2·5	2·5	2·5	2·5
Fore limb	47	33	44	42
Hand	16	12	15	15
Hind limb	60	43	59	56
Tibia	21	15	22	19
Foot	24	17	22	20
Tail	94	63	105	77

1, ♂, Cape of Good Hope (Busk). 2. ♂, Cape of Good Hope (Lea). 3. ♀, Cape Colony (Haslar Hosp.). 4. ♀, Eerste River (Leighton).

Lepidosis.—Upper parts very rough, with enlarged spinose scales on the posterior part of the head and on the body and limbs, scattered, or forming small groups among moderately large, imbricate, strongly keeled and sometimes more or less distinctly mucronate scales; 70 to 85 scales round middle of body; the longest spinose scales near the ear-opening as long as or a little longer than the diameter of the latter; a vertebral series of more or less distinctly enlarged scales, often forming a low but very distinct nuchal and dorsal crest, which may be interrupted on the back. Upper head-scales unequal, rough, keeled or subconical, one or two enlarged, usually one trihedral, in the middle of the forehead; occipital * enlarged, the pineal foramen in a crater-like pit, and surrounded by conical spinose scales; 9 to 13 scales across the head, from one superciliary edge to the other; 12 to 16 upper labials on each side; 2 to 4 series of scales between the upper labials and the nasal. Gular and ventral scales keeled, usually strongly, more or less mucronate, usually very strongly. Scale at the base of the claw, on the dorsal surface of the toes, uni- or tricarinate, and not or but little longer than the others; subdigital scales spinose, 12 to 16 in a longitudinal series under the third toe. Caudal scales strongly keeled and more or less distinctly mucronate, not forming whorls, equal except at the base, where their character partakes of that of the body. Male with a single row, exceptionally two rows † of rather small, sometimes very indistinct preanal pores.

* Representing the interparietal of other lizards. Following the example of previous authors, and for convenience, we have used the term "occipital" for this scale, although it is not homologous with that so-called in *Lacerta*.

† As noticed by Duméril and Bibron.

*Coloration.**—Brown, light grey, olive, or vivid green above; males with rather indistinct darker and lighter variegations; females, and some males, with two or four longitudinal and four or five transverse series of squarish dark brown, dark green, purplish, or blackish spots or cross-bars on the body, usually with a ʌ-shaped yellowish marking between the spots, on the vertebral line; also with dark cross-bars on the limbs and tail. Lower parts bluish grey or greenish blue in males, darker on the throat; yellowish or greyish white in females and young, often with a wide-meshed dark grey or black network on the belly.

Particulars of Specimens Examined.†

	1.	2.	3.	4.	5.	6.	7.	8.	9.
BRITISH MUSEUM:									
Cape of G.H. (Busk) ♂	88	94	23	60	21	24	4	2·5	3rd
,, (Townsend) ♂	73	74	19	48	17	19	4	2·5	3rd
,, (Lea) ♂	67	63	18	43	15	17	3·5	2·5	3rd
,, (Belcher) ♀	90	?	21	57	20	20	4	2	3rd
Eerste R. (Leighton) ♀	92	77	21	56	19	20	5	2·5	3rd
Cape Colony (Chatham Mus.) ♀	100	105	24	60	22	22	5	2·5	3rd
,, (,,) ♀	89	100	22	56	20	21	4	3	3rd
Little Namaqualand ♂	80	88	22	52	20	20	4	2·5	3rd
SOUTH AFRICAN MUSEUM:									
Claremont ♂	84	105	21	53	20	21	?	2	3rd
,, ♂	80	83	20	54	19	20	4	2	3rd
Cape Flats ♂	98	117	23	62	22	24	4	2	3rd
,, ♀	98	76	21	53	20	19	5	2	3rd
,, ♀	85	76	20	53	19	20	4	2	3rd
Calvinia ♀	98	90	22	54	19	20	4	2	3rd
Hondeklipbay ♂	89	99	20	54	21	22	4	2	3rd
KIMBERLEY MUSEUM:									
Somerset Strand ♂	85	102	20	55	19	20	3·5	2	3rd
,, ♂	79	88	20	50	16	19	4	1·5	3rd
,, ♂	70	80	17	45	16	18	3	1·5	3rd
,, ♀	83	6	17	46	16	19	3·5	2	3rd

* Owing to variability and power of colour-change possessed by the Agamas, as pointed out in the South African Journal of Science, 1917, p. 263, it is not possible to give adequate descriptions of the coloration. We have therefore limited ourselves to some general statements, which, we trust, may be found helpful for the purpose of identification.

† The nine columns read as follows in this as well as the other tables: 1. Length (in millimetres) from snout to vent. 2. Tail. 3. Head (to occiput). 4. Hind limb. 5. Tibia (from heel to knee). 6. Foot (including claw). 7. Length of cleft of closed eye. 8. Greatest diameter of ear-opening. 9. Longest toe. The localities are given according to latitude, beginning with the most southerly.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
ALBANY MUSEUM:									
Tulbagh ♂	86	107	20	56	20	21	3·5	2	3rd
„ ♂	72	80	17	47	17	18	3·5	2	3rd
„ ♀	76	73	17	49	17	19	3	2	3rd
„ ♀	70	63	16	45	17	18	3·5	2	3rd
TRANSVAAL MUSEUM:									
Cape of Good Hope ♀	87	96	19	47	17	18	3·5	2	3rd
Tulbagh ♀	66	61	15	43	15	15	3·5	1·5	3rd

Habitat.—The South-Western part of the Cape Colony.

This *Agama* seems to inhabit, generally speaking, undulating sandy country It is found among the sand-dunes on the Cape Flats, and the junior author has collected specimens on the grassy slopes of the hills behind Somerset West village. One specimen was captured on the roadside.

The food consists of plants and insects.

B. Var. BRACHYURA.

Agama brachyura, Bouleng. Cat. Liz. i, p. 350, pl. xxviii, fig. 1 (1885); and Proc. Zool. Soc. 1905, ii, p. 252.

This form, originally considered a species, was founded on a single specimen in the British Museum, a female without indication of locality but forming part of Sir Andrew Smith's South African Collection. The British Museum has since received specimens from Deelfontein, Klipfontein and Little Namaqualand which agree very closely with the type, and which unquestionably pertain to the same form in the narrowest sense. It is on this small material that the following description is based; but a larger series shows the characters to be inadequate for a sharp separation of this supposed species from *A. hispida*, and we have accordingly reduced its rank to that of a variety. The following description is taken from the specimens in the British Museum:

Form.—Habit very stout, body much depressed. Head short, convex, subcordiform, its width equal to or greater than its length to occiput; snout very short, rounded; canthus rostralis very short; nostril directed outwards and upwards, in the upper part of a convex but not tubular shield, pierced on or just below the canthus rostralis; length of head $3\frac{1}{2}$ to 4 times in length to vent. Diameter of ear-opening less ($\frac{1}{2}$ to $\frac{3}{4}$) than cleft of closed eye. Limbs moderately elongate; the hind limb reaches the shoulder or the neck, or merely the ear; length of hand equal to or greater than depth of head; fingers short, third longest; tibia as long as or a little longer than head or foot; toes short, fourth longer than third, or third and fourth equal, fifth not extending as far as first. Tail cylindrical, moderately or

very slender, a little longer or a little shorter ($\frac{5}{6}$ to $1\frac{1}{5}$ times) than head and body.

Measurements (in millimetres):

	1.	2.	3.	4.
From snout to vent	111	92	83	71
Head	27	23	21	19
Width of head	27	23	21	20
Depth of head	17	16	14	12
Diameter of eye-cleft	5	4·5	4	4
„ „ ear-opening	3	2·5	2·5	2·5
Fore limb	54	49	42	37
Hand	19	16	15	14
Hind limb	73	62	55	51
Tibia	27	21	20	18
Foot	27	23	21	20
Tail	129	82	90	63

1. ♂, Little Namaqualand. 2. ♀, Little Namaqualand. 3. ♂, Deelfontein. 4. ♀, S. Africa (type).

Lepidosis.—Upper parts rough with enlarged spinose scales as in *A. hispida*, but not so plentiful, more as in an average *A. aculeata*, the smaller scales strongly keeled and mostly mucronate; the largest spinose scales forming 3 or 4 longitudinal series on each side of the back; 80 to 90 scales round middle of body; the largest spinose scales near the ear-opening as long as or a little shorter than the diameter of the latter (shorter in the young); vertebral crest very low but distinct on the nape, just indicated or interrupted on the back. Upper head-scales unequal, rough, keeled or subconical, sometimes smooth on the snout and over the eyes, a few enlarged in the middle of the snout; some enlarged trihedral scales just behind or partly surrounding the enlarged occipital; the pineal foramen in the centre of a pit which may be shallow or deep and crater-like as in *A. hispida*; 11 to 15 scales across the head, from one superciliary series to the other; 11 to 15 upper labials on each side; 3 to 5 series of scales between the upper labials and the nasals. Gular and ventral scales smooth or faintly keeled, sometimes shortly mucronate. Scale at the base of the claw, on the dorsal surface of the toes, uni- or tricarinate and not, or but little, longer than the others; subdigital scales spinose, 14 to 18 in a longitudinal series under the third or fourth toe. Caudal scales strongly keeled, more or less distinctly mucronate, not forming whorls, equal except at the base. Scales on upper surface of tibia very unequal in size.

Male with a single row of rather small preanal pores.

Coloration.—Yellowish or greyish brown above, large males greenish olive, females sometimes reddish brown, with two or four longitudinal and

four or five transverse series of dark brown or blackish spots on the body, with an oval, square, Λ- or X-shaped light marking between the spots on the vertebral line. Limbs and tail with dark cross-bars. Lower parts yellowish white, pale olive in full-grown males, with a more or less distinct wide-meshed grey or dark olive network; throat of males blackish or bluish-green.

Particulars of Specimens Examined.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
BRITISH MUSEUM:									
S. Africa (type) ♀ . . .	71	63	19	51	18	20	4	2·5	4th
Deelfontein ♂ . . .	83	90	21	55	20	21	4	2·5	3rd & 4th
" ♀ . . .	86	77	21	55	20	22	4	2·5	3rd & 4th
" ♀ . . .	59	54	18	43	15	18	3·5	2	4th
Port Nolloth ♂ . . .	110	130	27	72	27	27	5	3	3rd & 4th
Little Namaqualand ♂ . .	111	129	27	73	27	27	5	3	3rd & 4th
" ♀ . .	92	82	23	62	21	23	4·5	3	4th
Klipfontein ♂ . . .	100	107	27	71	25	27	5	3	4th
" ♀ . . .	67	55	18	44	16	17	4	2	4th
" ♀ . . .	64	64	16	46	16	18	3·5	2	4th
SOUTH AFRICAN MUSEUM:									
Worcester ♂	91	111	21	66	24	25	4	2·5	4th slightly
Nelspoort, Beaufort W. ♀ .	79	72	17	48	17	17	3·5	2	3rd & 4th
Calvinia ♀	103	85	21	63	23	23	4	1·5	4th
Springbok, Steinkopf ♂ . .	93	110	21	63	21	24·5	4·5	2·5	4th
Port Nolloth ♂ . . .	98	110	21	71	24	27	4	2·5	4th
" ♂ . . .	121	146	26	77	27	28	6	3·5	4th
" ♂ . . .	95	111	23	64	22	24	4	3	4th
" ♀ . . .	99	93	21	59	21	22	4	2·5	4th
" ♀ . . .	81	95	19	60	21	22	?	2	3rd & 4th
" ♂ . . .	97	111	22	62	22	24	4	3	3rd
" ♂ . . .	111	127	25	64	26	23	5	3	4th
" ♂ . . .	109	123	28	65	25	27	5	3	3rd
" ♀ . . .	89	83	21	59	21	22	4	2	3rd
Ograbis ♂	99	123	22	69	24	25	?	3	4th
Aninous ♀	101	72	21	61	22	22	4	3	3rd & 4th
Grassmund, Little Namaqualand ♀	113	93	24	66	23	23	4·5	3	4th
" ♀	115	?	25	70	25	25	5	2·5	3rd & 4th
Aus ♀	101	96	20	66	22	24	4	2	4th
KIMBERLEY MUSEUM:									
Driekoppen ♀ . . .	72	85	18	47	17	18	3	2	4th
" ♀ . . .	76	73	17	48	18	17	4	3	3rd
Kuboos ♂	108	122	26	69	27	25	5	2·5	4th
Aus ♂	105	?	31	73	26	28	5	2·5	4th
" ♀	95	85	28	60	21	25	4	2	4th
" ♂	104	?	23	72	25	27	5	2·5	4th
" ♀	96	83	21	60	22	23	5	2·5	4th

	1.	2.	3.	4.	5.	6.	7.	8.	9.
ALBANY MUSEUM:									
Steinkopf ♂	113	126	25	72	26	25	4·5	3	4th slightly
„ ♀	102	88	19	62	22	23	4·5	3	4th

The following disagreements with the above description are to be noted;

1. The enlarged dorsal scales sometimes arranged in clusters at either side of the vertebral line.—Aus, Pt. Nolloth, Steinkopf, Nelspoort.

2. Enlarged scales scattered irregularly and few.—Pt. Nolloth.

3. Smaller dorso-laterals strongly keeled but not mucronate.—Aus, Kuboos, Pt. Nolloth.

4. A female from Aus has the smaller dorsals strongly keeled but not mucronate; ventrals strongly keeled and mucronate; head-scales smooth over the eyes and on the forehead.

5. A male from Namaqualand resembles this specimen, but the enlarged dorsals in this case are only slightly enlarged, and arranged in 3 longitudinal series on either side.

6. A female from Namaqualand has the enlarged dorsal scales in clusters; the third toe longest on the right foot, the fourth on the left.

7. Four enlarged scales in the middle of the snout.—Pt. Nolloth, Ograbis, Nelspoort, Grassmund.

8. Preanal pores apparently entirely absent.—Beaufort West, Steinkopf.

9. Preanal pores in two rows.—Pt. Nolloth.

10. The third toe longest on the right foot, the fourth on the left.—Aus, Pt. Nolloth.

11. The third toe longest.—Pt. Nolloth (3 specimens), Driekoppen (1 specimen). Otherwise agreeing with *A. brachyura.*

12. Toes long and slender.—Nelspoort.

13. Specimens from the farm "Driekoppen," Hanover Division, show a decided passage from *A. brachyura* to *A. distanti.* It is most difficult to place some of the specimens, as they exhibit the characters of both species in almost every possible combination.

One specimen has the ear-opening small as in typical *A. brachyura*, scaling rougher than in specimens of *A. distanti* from Pretoria, but the third toe longest; another has all the above characters but the fourth toe longest; while yet another has the ear-opening 3 mm. on one side, 2 mm. on the other, and the third and fourth toes equal.

A male from Namaqualand, and a female, probably from the neighbourhood of Pt. Nolloth, are very like *A. aculeata* but that the ear-opening is small and the toes are exceptionally long and slender. There are usually 3 or 4 enlarged, trihedral scales on the forehead with some smaller ones at either side, just behind and partly surrounding the occipital scale, which is usually slightly pitted.

Material from Nelspoort and Beaufort West may have the enlarged

dorsal scales arranged in clusters; upper head scales not so strongly keeled as usual; 4 enlarged trihedral scales on the forehead; occipital scale slightly pitted; ventrals perfectly smooth throughout; toes rather long and slender.

The lesser length of the third toe compared with the fourth has been regarded as the principal character for separating *A. brachyura* from *A. hispida*. However, the case above noted, of the third toe being the longer on the right foot and the fourth on the left, shakes our faith in its value, and we have in consequence referred to *A. brachyura* those specimens form Pt. Nolloth (South African Museum) which differ from others obtained in the same locality in no other important point. All we can say is that in the south-west parts of the Cape Province a rougher lepidosis coupled with a longer third toe (typical *A. hispida*) prevails. The more northern form may perhaps be maintained as distinct under the name of var. *brachyura*.

Agama hispida, var. *brachyura*, seems to inhabit arid regions, and is found at Aus in rocky localities. According to Capt. J. B. Knobel the neighbourhood of Aus is very rugged, but at some distance from it there is a good deal of grass veld, and at intervals some wind-blown sand. The country is bleak and bare except in the hollows, where the rain-water settles and enables a few trees to grow.

This variety is also found in the Karroo.

c. Var. DISTANTI.

Agama distanti, Bouleng. Ann. & Mag. N. H. (7) ix, 1902, p. 339.

The distinction of this form from *A. hispida* was originally based on specimens from Pretoria and Rustenburg, Transvaal, preserved in the British Museum. The following description is drawn up exclusively from these type specimens.

Form.—Habit very stout, body much depressed. Head short, convex, cordiform, its width equal to its length to occiput or slightly greater; snout very short, rounded; canthus rostralis very short; nostril directed outwards or outwards and upwards, in a convex but not tubular shield, pierced on or just below the canthus rostralis; length of head $3\frac{1}{3}$ to $4\frac{1}{3}$ times in length to vent. Diameter of ear-opening equal to or slightly greater than length of cleft of closed eye. Limbs moderately elongate; the hind limb, pressed against the body, reaches the shoulder or the neck (or the ear in young); length of hand equal to or a little less than depth of head; fingers short, third longest; tibia shorter than the head, as long as or slightly shorter than the foot; toes short, third longer than fourth, fifth not extending as far as first. Tail cylindrical, moderately or very slender, a little longer or shorter than head and body ($\frac{3}{4}$ to $1\frac{1}{4}$).

Measurements of type specimens, in millimetres:

	1.	2.	3.	4.
Snout to vent . .	82	80	83	75
Head . . .	21	19	20	18
Width of head . .	21	20	20	18
Depth of head . .	14	12	13	12
Diameter of eye-cleft .	4	3·5	3·5	3·5
,, ,, ear-opening	4	3·5	4	3·5
Fore limb . . .	34	31	36	34
Hand . . .	12	11	13	12
Hind limb . . .	49	45	48	44
Tibia . . .	17	16	17	15
Foot	17	16	17	16
Tail	100	77	62	59

1. ♂, Pretoria. 2. ♂, Rustenburg. 3, 4. ♀, Pretoria.

Lepidosis.—Upper parts rough with enlarged spinose scales as in *A. hispida*, but often not so strongly, the smaller scales very small, strongly keeled but not mucronate (except low down on the sides); 85 to 110 scales round the middle of the body*; some of the spinose scales may form longitudinal series on the back; the largest spinose scales near the ear-opening shorter than the diameter of the latter; vertebral crest very low but distinct on the nape, just indicated or absent on the back. Upper head-scales unequal, and more or less strongly keeled, 3 to 5 enlarged in the middle of the snout; occipital enlarged; 12 to 16 scales across the head from one superciliary series to the other; 11 to 16 upper labials on each side; 2 to 4 series of scales between the upper labials and the nasal. Gular and ventral scales smooth or faintly keeled, not or but very shortly mucronate, except on the sides. Upper scale at base of claw not or but slightly longer than the others; 12 to 15 scales in a longitudinal series under the third toe. Caudal scales strongly keeled, feebly mucronate, not forming whorls, equal except at the base, where their character partakes of that of the body. Scales on upper surface of tibia very unequal in size. Male with a single row of rather small preanal pores.

Coloration.—Greyish olive or brown above, with a yellow vertebral stripe from the occiput to the tail, where it merges into the pale colour of that organ; this vertebral stripe may be incompletely divided by an interrupted dark line along the median series of scales; back uniform (females) or with large squarish dark brown spots forming a series on each side of the vertebral stripe; upper surface of head with symmetrical dark and light markings, in the form of bars or chevrons between the eyes; head sometimes blackish above (female from Pretoria); limbs and tail with dark cross-bars. Lower

* The range of variation for all the specimens in the British Museum is 85 to 115.

parts white, throat with blueish or blackish wavy longitudinal lines or vermiculations.

We have now examined many more specimens, enumerated hereafter, some of which disagree with the types in important respects:

Particulars of Specimens Examined.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
BRITISH MUSEUM:									
Pretoria (type) ♂	82	94	21	49	17	18	4	4	3rd
,, ,, ♂	77	89	21	52	19	20	4	4	3rd
,, ,, ♂	66	?	16	50	17	18	3	3	3rd
,, ,, ♂	54	65	16	37	14	15	3	3	3rd
,, ,, ♂	53	60	16	39	13	15	3	3	3rd
,, ,, ♂	49	49	15	34	12	14	2·5	2·5	3rd
,, ,, ♀	83	62	20	48	17	17	3·5	4	3rd
,, ,, ♀	75	59	18	44	15	16	3·5	3·5	3rd
,, ,, ♀	62	67	16	42	14	18	3·5	3·5	3rd
Rustenburg (type) ♂	80	77	19	45	16	16	3·5	3·5	3rd
,, ,, ♀	60	61	17	41	14	15	3	3	3rd
Barberton, Transvaal ♂	84	110	22	49	19	19	4	4	3rd
,, ,, ♂	79	100	20	46	16	17	4	4	3rd
Wolmeransted-Bloemhoff, Transvaal ♂	69	?	17	46	16	17	4	4	3rd
Zoutpanberg, Transvaal ♀	66	82	18	46	16	17	3	3	3rd
,, ,, ♀	57	65	16	40	15	16	2·5	2·5	3rd
Woodbush, ,, ♂	61	90	18	43	14	16	3	3	3rd
Tweespruit, **O.F.S.** ♂	55	55	17	40	14	15	3	3	3rd
,, ,, ♀	80	67	22	49	18	19	4	4	3rd
Vredefort Rd., **O.F.S.** ♂	75	81	19	52	19	20	3·5	3·5	3rd
,, ,, ♂	73	83	19	57	20	20	3·5	3·5	3rd
,, ,, ♂	70	76	18	46	16	17	3	3	3rd
,, ,, ♂	69	?	18	48	18	18	3	3	3rd
,, ,, ♂	60	60	16	43	15	16	2·5	2·5	3rd
,, ,, ♀	81	70	19	53	19	20	3	3	3rd
,, ,, ♀	77	68	19	52	18	19	3	3	3rd
,, ,, ♀	76	63	19	52	19	20	3·5	3	3rd
,, ,, ♀	71	61	18	45	17	17	3·5	3	3rd
Bulawayo ♂	90	130	23	57	20	21	4	4	3rd
,, ♂	88	122	22	52	19	19	4	4	3rd
,, ♂	80	116	19	54	19	20	4	4	3rd
,, ♂	70	89	18	44	15	16	3	3	3rd
,, ♀	90	90	22	51	19	19	4	4	3rd
,, ♀	73	70	18	40	15	16	3	3	3rd & 4th
,, ♀	85	85	22	50	17	19	4	4	3rd
Mazoi, Mashonaland ♂	68	86	18	43	15	16	3	3	3rd
,, ,, ♂	59	?	16	41	14	15	3	3	3rd
,, ,, ♂	50	58	15	35	12	14	2·5	2·5	3rd & 4th
,, ,, ♀	49	55	14	35	12	14	2·5	2·5	3rd

	1.	2.	3.	4.	5.	6.	7.	8.	9.
TRANSVAAL MUSEUM:									
Potchefstroom ♀	70	60	17	44	16	15	3·5	2·5	3rd
" ♂	73	78	18	47	17	17	3·5	2	3rd
" ♀	83	?	18	48	18	17	3	3	3rd
" ♂	78	85	18	51	19	18	3	2·5	3rd
Meintjes Kop ♀	74	53	16	40	14	14	3	2·5	3rd
Woodbush ♀	80	58	18	41	18	18	3	3	3rd
Pretoria ♀	78	64	16	43	15	16	3	3	3rd
Woodbush ♀	77	66	23	42	14	16	3	2	3rd
Pretoria ♂	70	78·5	16	48	17	18	3	3	3rd
" ♂	79	97	17	45	16	17	3	2	3rd
" ♀	68	56	16	41	14	16	?	2	3rd
Silverton ♂	80	88	18	48	16	18	3	3	3rd
Meintjes Kop ♀	69	56	15	43	15	16	3	3	3rd
Pretoria ♀	70	64	17	44	15	16	3	2	3rd & 4th
Meintjes Kop ♂	75	82	17	49	15	19	3	3	3rd
Pretoria ♀	73	59	15	45	16	16	3	2	3rd
" ♂	79	?	17	46	16	17	3	3	3rd & 4th
" ♂	74	80	17	47	16	17	3·5	3	3rd
" ♀	79	57	17	47	15·5	17	3	3	?rd
" ♀	72	63	16	46	14	17	3	3	3rd
" ♂	84	87	19	49	17	18	3	3	3rd
" ♂	75	87	16	48	16	18	3	2·5	3rd
" ♂	76	91	17	49	15	18	3	2·5	3rd
" ♂	83	88	19	54	17	20	3	3	3rd
" ♂	80	104	19	51	16	20	3·5	3·5	3rd
Woodbush ♀	78	65	18	40	14	15	3·5	2·5	3rd
Meintjes Kop ♂	70	83	16	45	14	16	3·5	3	3rd
Pretoria ♀	74	64	17	45	14	17	3	3	3rd
" ♀	77	64	16	43	14	16	3	3	3rd
" ♀	76	61	16	45	14	17	3	3	3rd
Wonderboom ♀	79	?	16	43	13	16	3	3	3rd
Hornsnek ♀	73	62	17	49	15	18	3	3	3rd
Pretoria ♀	88	62	23	47	15	17	3	3	3rd
" ♀	78	65	17	47	15	18	3	3	3rd
" ♂	66	77	15	42	14	17	3	2	3rd
" ♀	75	76	17	42	13	16	3	2	3rd
Woodbush ♀	75	63	16	40	12	16	3	2	3rd
Pretoria ♂	70	73·5	17	49	18	18	3	3	3rd
" ♂	70	78	15	44	16	16	3	2·5	3rd
" ♀	70	65	16	43	15	16	2·5	2·5	3rd
Goedgedacht ♂	75	94	17	46	14	17	3·5	3	3rd
Witpoort ♀	76	61	17	46	15	17	3·5	3·5	3rd
" ♀	87	63	19	47	15	16	3	2	3rd
Zandfontein ♂	75	84	18	47	17	17	3	3	3rd
" ♀	85	79	20	48	16	17	4	3	3rd
" ♀	79	74	17	48	15	17	3	3	3rd
" ♂	69	85	16	46	14	18	3	3	3rd
Quaggaspoort ♀	62	50	15	39	13	14	3	3	3rd

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Magaliesberg ♂	78	88	17	45	16	17	3	2	3rd
„ ♂	62	71	20	43	14	16	3	2	3rd
„ ♂	65	70	15	41	15	15	3	2	3rd
Kaalplaats ♂	78	?	17	48	16	17	3·5	2·5	3rd
Zoutpan ♂	78	104	18	48	15	19	3·5	3	3rd
„ ♀	75	61	15	40	13	17	3	3	3rd
Rosslyn ♂	80	97	19	49	15	18	3	3	3rd
Vygeboompoort ♂	65	94	17	44	14	16	3	2·5	3rd
„ ♂	65	80	15	44	14	16	3·5	2·5	3rd
„ ♂	76	99	17	46	15	18	3	3	3rd
„ ♂	69	102	16	43	14	16	3·5	3	3rd & 4th
„ ♂	68	81	16	44	14	16	3	3	3rd
„ ♀	66	69	16	41	15	17	3	3	3rd
„ ♀	59	56	15	38	13	16	3	3	3rd
„ ♂	66	80	15	44	15	17	3	3	3rd
Waterberg ♂	75	105	22	45	15	17	3·5	3	3rd
„ ♂	67	88	20	44	15	17	3	3	3rd
„ ♂	76	105	17	43	15	17	3	2·5	3rd
Lydenburg ♀	80	58	17	45	14	16	3·5	3·5	3rd
Metlepetsi River ♂	79	101	18	46	15	19	3·5	2	3rd & 4th
Pietersburg ♂	64	74	16	44	14	17	3	2	3rd
Selati River ♀	98	83	20	47	15	18	3·5	3	3rd
„ ♂	65	78	16	45	14	17	3	2·5	3rd
Zand River ♀	75	75	17	47	15	17	3	2·5	3rd
„ ♀	65	66	16	42	15	16	3	3	3rd
Bandolier Kop ♂	89	?	20	48	18	18	3·5	3	3rd
Transvaal ♀	81	70	19	45	14·5	17	4	3	3rd
„ ♀	76	?	18	46	15	16	3	3	3rd
Kimberley Museum:									
Driekoppen ♀	76	74	17	49	18	18	3·5	2·5	3rd
Bloemfontein ♂	60	?	19	44	15	17	3	2	3rd
Thaba 'Nchu ♂	75	83	17	52	18	19	3·5	3	3rd
„ ♂	67	69	16	45	16	17	3·5	2·5	3rd
„ ♂	71	73	18	48	17	18	3·5	2·5	3rd
Vryburg ♂	73	?	19	46	17	17	3·5	3·5	3rd
„ ♂	85	123	23	52	19	20	4	4	3rd
„ ♀	56	59	17	38	16	15	3	2·5	3rd
Devondale ♀	77	65	16	45	17	17	2·5	2·5	3rd
Kraaipan ♀	90	80	18	52	19	19	3·5	4	3rd
„ ♀	88	74	23	49	18	17	3·5	3	3rd
Ramathlabama ♀	60	67	17	40	15	16	3	3	3rd
Otto's Hoop ♀	85	?	19	48	17	18	4	3	3rd
Pretoria ♂	74	82	22	47	17	19	3	3	3rd
„ ♂	82	103	20	50	18	18	4	3	3rd
Steyensburg ♀	70	55	17	46	15	17	3·5	3	3rd
Baralong Farms ♀	84	72	18	46	17	18	3	3	3rd
„ ♀	83	67	19	49	17	18	3·5	3	3rd
Pienaar's River ♀	87	?	18	47	16	16	3·5	3·5	3rd

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Pienaar's River ♂	78	84	17	48	17	18	3·5	3·5	3rd
„ ♀	90	85	20	51	17	17	3·5	3·5	3rd
„ ♀	82	71	18	45	16	16	3·5	3·5	3rd
„ ♀	84	67	18	45	17	17	3·5	3	3rd
„ ♂	82	115	19	52	18	19	4	3	3rd
„ ♀	82	75	17	44	16	16	4	4	3rd
„ ♂	81	101	18	50	18	18	4	3	3rd
„ ♂	81	104	18	49	18	18	3·5	3·5	3rd
„ ♂	86	107	19	50	18	19	3·5	3	3rd
„ ♀	77	72	17	46	15	17	3	3	3rd
„ ♀	68	66	16	41	14	16	3	3	3rd
„ ♀	77	62	17	46	16	17	3	3	3rd
„ ♂	80	115	18	50	18	17	3·5	3	3rd
„ ♂	82	95	18	50	18	20	3	3	3rd
Towani ♂	71	104	17	48	17	18	3·5	3	3rd
„ ♂	73	101	17	44	15	17	3·5	3	3rd
South African Museum:									
Burghersdorp ♀	74	60	17	46	16	17	3	3	3rd
„ ♂	70	70	16	46	16	17	3	3	3rd
„ ♂	70	65	16	48	17	18	3	2	3rd
Smithfield ♀	68	69	18	46	16	16	3·5	3	3rd
„ ♀	83	73	23	52	20	20	4	3	3rd
O'okiep ♀	72	62	18	51	17	19	3·5	3·5	3rd
„ ♂	71	71	16	48	17	19	3	3	3rd
Vredefort Road ♀	71	66	15	45	15	16	3	2·5	3rd
„ ♀	75	91	16	50	17	19	?	3	3rd
„ ♂	74	92	16	49	18	19	3	2·5	3rd
Mochudi ♀	79	88	17	49	17	19	?	3	3rd
„ ♀	91	84	19	50	17	19	3·5	3	3rd
„ ♂	94	121	20	53	19	20	4	3	3rd
„ ♂	85	110	20	50	18	19	4	4	3rd
Salisbury ♀	77	87	23	44	16	17	3	3	3rd
Schishawasha ♂	73	102	19	46	18	18	3	3	3rd
„ ♂	73	?	18	44	17	18	3	2·5	3rd & 4th
„ ♀	78	61	22	41	15	16	3·5	3	3rd
„ ♀	76	87	18	43	16	16	3	3	3rd
Mazoe ♂	78	96	18	45	16	16	4	3	3rd
„ ♀	79	?	18	40	15	15	3·5	3	3rd
Bindura ♀	79	87	18	45	16	16	3·5	3·5	3rd
Impotuni Dis., Rhod. ♂	73	95	17	46	16	18	3	3	3rd
Albany Museum:									
Bloemfontein ♀	82	66	20	47	18	18	3	3	3rd
Potchefstroom ♂	65	73	16	42	16	17	3	2	3rd
Pretoria ♂	75	93	17	43	16	16	3	3	3rd
Doornkop ♀	79	65	24	43	16	16	3	3	3rd
„ ♀	80	?	19	45	16	16	3	3	3rd
„ ♀	68	63	16	40	15	16	3	2	3rd
„ ♂	74	86	19	47	17	17	3·5	3	3rd
„ ♀	70	58	16	43	15	16	3	2	3rd

The following observations are a result of the study of the whole material.

First with reference to the collection in the British Museum :

The length of the head may be 4¼ times that of the head and body ; the tibia may equal or even slightly exceed the length of the head ; the third and fourth toes are exceptionally equal ; the fifth toe may extend as far as the first (two males from Barberton, two from Vredefort Road and two from Bulawayo, two females from Bulawayo, all the specimens from Mazoe) ; the tail may be 1½ times as long as the head and body. Ventral scales feebly but very distinctly keeled and mucronate in a female from Vredefort Road, also in a male and female from Bulawayo. Two series of preanal pores ; up to 19 scales under the third toe in a male from Bulawayo and in another from Mazoe.

The collections in the museums of South Africa :

The enlarged dorsal scaling as in typical specimens of *A. aculeata* (Pienaar's River, Selati River, Metlepetsi River).

Fifth toe extending as far as the first (Pienaar's River, Towani, Pretoria, Witpoort, Kaalplaats, Waterberg, Zand River, Metlepetsi River).

Head broader than long (Pretoria).

Toes slender (Pretoria, Witpoort, Kaalplaats, Selati River, Zand River, Metlepetsi River).

Head longer than broad (Pretoria, Rosslyn, Magaliesberg).

Two cases were noted where the preanal pores were in two rows.

The following combinations of characters were noticed in individual specimens :

1. Otto's Hoop ♀. Dorsal scaling exceptionally rough and mucronate throughout ; enlarged spinose scales on the sides of the head and neck ; ventrals smooth.

2. Thabanchu ♂. Ventrals smooth ; enlarged dorsals not in longitudinal series ; head-scales as in *A. aculeata* from Kimberley.

3. Baralong Farms ♀. Ventrals slightly keeled on the chest and abdomen ; dorsal scaling as in *A. aculeata*, by no means very rough ; tail very compressed laterally, not crested.

4. Pienaar's River 3 ♂ ♀. The fifth toe extending as far as the first.

5. Pretoria ♀. Head-scales very strongly keeled, subconical on either side of the occiput ; enlarged dorsal scales arranged in two longitudinal series about the centre of each side, those in the centre of the back arranged in 4 clusters round 4 lighter spots ; smaller dorsals strongly keeled but not mucronate.

6. Vygeboompoort ♂. Third toe slightly longer than the fourth on the right foot, same toes equal on the left foot. Two similar cases of this are noticed. Several specimens from this locality are most difficult to place.

7. Pretoria ♀. Head slightly longer than broad; fifth toe extending as far as the first; ventrals feebly keeled.

8 Zoutpan ♀. Large scales very few; toes fairly slender; scales on upper tibia equal; head-scales only very feebly keeled. This specimen seems to be near *A. armata.*

9. Vygeboompoort ♂. Toes and dorsal scaling as in typical *A. armata.* Otherwise the same as *A. distanti.*

10. Vygeboompoort ♀. Dorsal scaling, head and toes as in typical *A. armata.* Ventrals feebly keeled; scales on upper surface of tibia unequal.

11. Metlepetsi River ♀. Toes rather slender, fifth extending as far as the first; dorsal scaling like that of *A. aculeata*; scales on upper surface of tibia very unequal.

12. Doornkop ♀. Head and dorsal scaling very like those of *A. armata.* Ventrals rather strongly keeled, but not mucronate; toes short and thick, fifth not extending as far as the first. Another female from the same locality has a very rough head-scaling, it being subconical throughout.

13. Mazoe ♂. General appearance like *aculeata*; fifth toe extends as far as the first; scales on upper surface of tibia sub-equal.

14. Mazoe ♀. Fairly typical as regards dorsal scaling; ventrals feebly but distinctly keeled, strongly so and mucronate on the chest and sides. Head much longer than broad.

15. Bindura, ♀. Dorsal scaling as in *A. armata;* scales on upper tibia unequal; feet and toes like *A. distanti,* except that the fifth toe extends as far as the first. Ventrals feebly but distinctly keeled throughout. Head like *A. armata.*

16. Schishawasha ♀. Dorsal scaling by no means rough; no trace whatever of a dorsal crest.

17. Smithfield ♀. Shows very rough scaling, not unlike specimens from Otto's Hoop.

Another specimen labelled "Mashonaland" has the general appearance of *A. aculeata;* the fifth toe extends as far as the first; scales on upper surface of tibia subequal.

Two males and two females from Mochudi are exactly like *A. aculeata,* except that the third toe is the longest, and in the case of two of them the fifth toe does not extend as far as the first. A female is the same as *A. aculeata* in every respect, save that the third toe is much longer than the fourth.

A half-grown specimen from Setlagoli has the scaling and other particulars exactly as in *A. distanti,* but the fourth toe is the longest.

One example from Driekoppen, Hanover Division, referred by us to this variety, greatly resembles those from Thaba 'Nchu. Others from the same localities have the ear-opening somewhat smaller than is generally the case in specimens from the Transvaal.

The scaling reaches its maximum roughness in specimens from Otto's Hoop (which are almost as rough as typical specimens of *A. hispida*); further north these give place to a variation with a lepidosis not nearly as rough, and on the north-west the scaling becomes almost typical of *A. aculeata* (Plumtree and Bulawayo). These again give place on the north-east to a group which merges gradually into *A. armata*.

The material examined by the junior author shows conclusively that not one of the characters adduced for the specific distinction of *Agama distanti* is constant. Yet by using the following characters in combination it may be possible to distinguish the form as a variety.

From *A. hispida*, by the larger ear-opening (with about 20 per cent. exceptions), by the less tubercular head-scales, with or without a shallow pit in the pineal scale, fewer scales round the body (85 to 115, usually at least 90, instead of 70 to 85), smooth or feebly keeled ventral scales.

Whenever the ventral scales are strongly keeled (1 specimen Pienaar's River, 1 Potchefstroom, 1 Pretoria, 1 Witpoort, 2 Doornkop), either the ear-opening is larger than in *A. hispida* or the head-scales are less tubercular. The shorter fourth toe in conjunction with the larger ear-opening will in most cases suffice for the distinction from *A. brachyura*, which has 80 to 90 scales round the body.

From *A. aculeata* by the shorter fourth toe, but when, as rarely happens in *A. distanti*, the third and fourth toes are equal, it will be necessary to resort to the generally unequal size of the scales on the tibia and the shorter tail of the latter. But uncertainty will result in many cases, and it must be admitted that the identification of certain specimens such as a few from Kimberley will be arbitrary.

From *A. armata* the distinction will be more difficult and more arbitrary still. We have based it on combinations of characters: shorter hand, less slender toes, more irregular lepidosis of the back and tibia (85 to 115 scales round body *versus* 73 to 100), but with unsatisfactory results, and it seems hopeless to attempt a comparative definition of the two forms except as applying to the majority of the specimens from a given district.

Such being the state of things, we are driven to the conclusion that *A. distanti* cannot be regarded as a species, and that its claims to rank as a variety can only be accepted in so far as that conception expresses an ill-defined grade in evolution.

According to P. A. Methuen this form is generally found on the plains, but sometimes also in valleys or at the bases of kopjes, where stones may be present. It occasionally climbs the thorn trees at a height of six feet or more.

The food consists largely of termites, for which it burrows into the nests.

D. Var. ACULEATA.

Agama aculeata, Dum. & Bibr. Erp. Gén. iv, p. 499 (1837); Bouleng. Cat. Liz. i, p. 351 (1885).

Agama infralineata, Peters, Mon. Berl. Ac. 1877, p. 613.

This is certainly the Agama so named by the authors of the Erpétologie Générale, but doubts may be entertained as to its being the *A. aculeata* of Merrem, which is probably a synonym of *A. hispida*. The name is therefore only used provisionally. The senior author has recently united this form with *A. armata*, but we now believe the two deserve to be upheld as distinct varieties, the latter differing in its typical form in the head being longer than broad and the ventral scales decidedly keeled; however, there are so many annectant specimens that a specific separation is not warranted.

Description of the specimens in the British Museum:

Form.—Body more depressed than usual in *A. armata*. Head as long as broad; snout short, rounded; canthus rostralis very short; nostril directed outwards, in a convex but not tubular shield, pierced on or just below the canthus rostralis; length of head $3\frac{3}{4}$ to $4\frac{2}{5}$ times in length to vent. Diameter of ear-opening equal to or a little less than cleft of closed eye. Limbs short or moderately elongate; the hind limb, pressed against the body, reaches the shoulder, the neck, or the ear; length of hand equal to or greater than depth of head; fingers and toes as in *A. armata*; tibia as long as, or shorter or longer than the head, shorter than the foot. Tail cylindrical, moderately slender, longer ($1\frac{1}{8}$ to nearly $1\frac{1}{2}$) than head and body.

Measurements:

	1.	2.	3.	4.
Snout to vent	105	80	83	93
Head	24	21	21	21
Width of head	24	21	21	21
Depth of head	16	12	14	13
Diameter of eye-cleft	4·5	4·5	4	4
,, ,, ear-opening	4	4	4	3·5
Fore limb	47	37	40	45
Hand	18	14	15	16
Hind limb	68	55	52	58
Tibia	24	19	18	21
Foot	27	21	19	22
Tail	154	105	?	120

1. ♂, Kimberley. 2. ♂, Okwa, Bechuanaland. 3. ♀, Ladysmith. 4. ♀, Damaraland.

Lepidosis.—Upper parts with strongly keeled scales, some or all shortly mucronate, with more or less enlarged ones which are strongly muconate and

disposed in 3 more or less regular longitudinal series on each side of the back; 75 to 100 scales round the middle of the body; groups of spinose scales on the side of the neck and near the ear-opening, the largest much shorter than the diameter of the latter; a low but very distinct dorsal crest, usually continued on the anterior part of the tail. Upper head-scales unequal, smooth or feebly keeled, one or two transverse series on the occiput more or less enlarged and subconical; occipital enlarged, not or but feebly pitted; 10 to 15 scales across the head from one superciliary series to the other; 10 to 15 upper labials on each side; 2 to 4 series of scales between the upper labials and the nasal. Gular and ventral scales smooth or feebly keeled, not or but slightly mucronate. Upper scale, at base of claw, not or but slightly longer than the others; 15 to 20 scales in a longitudinal series under the third or fourth toe. Caudal scales strongly keeled and mucronate, not forming whorls, more or less unequal in size. Scales on upper surface of tibia usually equal in size.

Male with a single row of rather small preanal pores.

Coloration.—Pale brown, light yellow, yellowish brown, dark brown or greyish above, uniform, or with dark brown or blackish spots (4 on either side of the vertebral line), or wavy cross-bars (2 on the nape, 4 on the back), sometimes with a series of large light spaces between the dark ones on the vertebral line, and a ♀ -shaped light mark on the nape, or with a light vertebral stripe, with a wavy lateral one at either side, sometimes with two dark cross-bars on the head, between the eyes, or with a V-shaped light mark between the eyes and a light bar across the forehead in front of the eyes; sides and top (just over occiput) of head, in males, sometimes blue-green or blackish, limbs and tail with more or less distinct dark cross-bars. Females sometimes exhibit larger blood-red blotches at either side of the vertebral line. Lower parts white, throat often with bluish or blackish wavy longitudinal lines, in males with a central blackish blotch or even entirely black, belly sometimes with traces of a dark network or of wavy longitudinal lines. Neck, chest and sides brick red in breeding males.

Particulars of Specimens Examined.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
BRITISH MUSEUM:									
S. Africa ♂	105	148	24	68	24	27	4·5	4	4th
Deelfontein ♂	69	86	17	50	17	18	3·5	3	4th
Ladysmith ♂	75	100	20	52	17	20	4	3·5	3rd
" ♂	59	74	16	43	15	17	3·5	3·5	3rd
" ♀	83	?	21	52	18	19	4	4	3rd
Okwa, Bechuanaland ♂	80	105	21	55	19	21	4·5	4	4th
" " ♂	73	98	18	49	17	19	4	3·5	3rd & 4th
" " ♂	61	80	16	40	13	16	3	2·5	3rd & 4th

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Tango, Bechuanaland ♂ .	58	68	15	40	13	15	3·5	3	3rd
" " ♂ .	58	66	15	41	13	16	3·5	3	3rd & 4th
Mopani Forest, Bechuanaland ♀	62	75	17	44	15	16	3·5	3	3rd
Gt. Karas Mt., S. Namaqualand ♀	88	117	21	60	21	23	4·5	4	4th
Damaraland ♀ . . .	93	120	21	58	21	22	4	3·5	3rd & 4th
" ♀ . . .	75	?	18	55	18	21	4	3	4th
" ♀ . . .	69	97	17	49	17	19	3·5	3·5	4th
KIMBERLEY MUSEUM:									
Van der Byl's Kraal ♀ . .	99	109	21	61	21	23	4	3	4th
De Aar ♀	86	?	19	55	19	21	3	4	4th
" ♀	85	98	20	56	20	21	4	3	4th
Britstown ♂	76	104	19	54	18	22	4	3	4th
Fort Richmond ♀ . .	101	112	21	57	20	22	4	3	4th
" ♂ . .	105	151	23	64	21	23	4	3	4th
" ♂ . .	100	143	23	63	23	23	4	3	4th
Belmont ♂	79	110	18	52	18	20	4	2·5	4th
Spreeuwfontein, ♂ . .	84	116	20	55	19	21	3·5	3·5	4th
Enslin ♂	92	122	21	59	20	23	4	4	4th
" ♂	93	130	20	59	20	22	4	4	4th
" ♂	106	155	23	65	22	23	4	3·5	4th
" ♂	83	113	19	47	19	23	3	3	4th
Upington ♂	103	160	23	59	23	26	4	3	4th
" ♀	83	100	18	58	18	22	3	3	4th
" ♀	73	87	19	52	18	21	3·5	3·5	4th
" ♀	18	?	20	58	20	22	4	3	4th
" ♀	70	100	18	51	18	21	3·5	3·5	4th
Modder River ♀ . . .	95	103	21	54	18	20	4	3	4th
" ♂ . . .	98	136	22	59	22	22	4	3	3rd & 4th
" ♀ . . .	90	109	21	56	21	21	4	3	3rd & 4th
Kimberley ♀	76	?	18	54	18	20	4	3	4th
" ♂	95	139	21	61	22	22	5	4	4th
" ♂	81	102	20	57	20	21	4	3	3rd & 4th
" ♀	95	107	21	59	21	22	4	3	4th
" ♀	83	?	19	52	19	21	4	3	4th
" ♂	91	125	21	59	20	23	4	3	4th
" ♂	101	153	23	61	21	22	5	4	3rd & 4th
" ♀	90	83	20	54	18	22	4	3	3rd & 4th
" ♂	94	?	21	60	20	24	4	3	3rd & 4th
" ♀	71	80	18	49	18	20	3	2	4th
" ♂	91	131	21	59	21	23	4	3	4th
" ♂	98	155	21	59	21	23	4	3	4th
" ♀	88	106	19	53	19	21	4	4	4th
" ♀	110	110	23	58	22	23	4	4	3rd
" ♂	98	137	24	66	22	24	4	3	4th
" ♀	102	?	21	57	21	22	4	3	4th
" ♂	104	145	24	64	23	24	4	4	4th slightly
" ♂	106	120	23	55	20	21	5	3	3rd & 4th

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Kimberley ♂	106	146	24	69	24	25	4	4	4th
,, ♂	112	?	24	71	24	26	4	4	4th
,, ♂	72	98	19	53	18	21	3·5	2	3rd & 4th
,, ♀	94	110	20	59	20	20	4	4	3rd & 4th
,, ♂	98	118	22	56	21	25	4	4	3rd & 4th
,, ♂	111	156	24	69	24	26	5	4	3rd & 4th
,, ♀	82	?	19	53	19	20	4	3·5	4th
,, ♀	93	99	20	56	20	20	3·5	3·5	3rd
,, ♂	92	130	19	61	19	23	4	4	4th slightly
,, ♂	105	140	23	68	23	25	4	4	4th slightly
,, ♂	103	144	21	64	21	23	4	4	3rd & 4th
,, ♂	106	144	22	64	22	25	4	4	3rd & 4th
Barkly West ♀	98	122	21	61	21	23	4	3·5	4th
Riverton ♀	98	?	21	57	21	22	4	3	3rd & 4th
,, ♀	83	?	19	55	19	20	?	2·5	4th
Delport's Hope ♀	68	?	18	50	17	20	3	3	3rd & 4th
,, ♀	102	126	21	59	21	22	4·5	4·5	4th
,, ♀	90	97	19	54	19	21	4	3	4th
,, ♂	94	127	21	57	19	22	4	4	3rd & 4th
,, ♂	89	?	20	63	20	24	5	4	3rd & 4th
Daniel's Kuil ♀	73	97	19	53	17	21	3·5	3	4th
,, ♂	94	?	22	67	22	26	4	4	4th slightly
,, ♂	76	101	18	56	17	23	3·5	3·5	4th
,, ♂	92	?	22	64	21	25	3·5	4	4th
,, ♂	74	?	18	50	17	20	3·5	3	4th
,, ♀	75	?	19	60	19	23	3·5	3·5	4th
Kuruman ♂	97	?	23	67	22	25	4	3	4th
Lower Molopo* ♂	87	111	21	61	21	24	4	4	4th
,, ♂	92	?	21	64	21	26	3	3	4th
,, ♂	89	146	20	54	20	25	4	4	4th
,, ♂	103	152	22	64	22	26	4	4	3rd & 4th
,, ♂	112	171	24	66	24	24	4	3	4th
,, ♀	80	102	20	57	20	23	3·5	3·5	4th
,, ♀	72	100	22	55	22	23	3	3	4th
Taungs ♀	63	88	15	45	15	18	3	3	4th
,, ♂	94	121	20	61	21	23	4	3	4th
Zwart Modder-Rietfontein ♂	104	154	23	63	23	24	4	3	4th
,, ,, ♀	94	127	21	58	20	22	4	3	4th
Watersmeet ♀	94	92	21	59	21	22	4	3	4th
Vryburg ♀	89	112	19	48	19	20	3	3	4th slightly
Dry Harts River ♂	80	?	19	58	19	22	3·5	3	4th
Genesa ♂	108	158	24	66	23	25	4	4	4th
,, ♂	108	?	23	63	23	23	4	4	4th
,, ♀	96	106	21	58	20	22	4	3	3rd & 4th
,, ♀	69	93	17	48	16	19	3	3	4th
,, ♀	65	88	16	46	16	19	3	2·5	4th

* The course of the Molopo River between its junction with the Nosob River and Smalvisch Kop.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Lower Nosob* ♂	98	?	22	64	22	26	5	4	4th
,, ♂	110	143	23	65	22	26	4	4	4th
,, ♂	83	?	?	61	21	23	4	3	4th
,, ♂	103	168	24	64	22	24	4	3	4th
,, ♂	104	153	23	61	23	25	4	4	4th
,, ♂	109	163	23	64	23	26	5	4	4th
,, ♂	99	144	23	61	23	25	4	4	4th
,, ♀	90	123	21	60	21	24	4	4	4th
,, ♀	79	106	18	53	18	21	4	3	4th
,, ♀	76	107	18	52	18	22	4	3	4th
,, ♂	113	?	25	66	25	26	4	4	4th
,, ♀	82	106	18	53	18	21	3	3	3rd & 4th
,, ♀	86	?	20	52	20	21	4	3	4th
,, ♀	73	105	19	51	18	20	3	3	4th
Ky Ky ♂	100	143	22	62	22	24	4	3	4th
,, ♂	92	118	22	65	22	25	4	4	4th
,, ♂	109	152	24	63	24	26	4	4	4th
,, ♂	101	149	23	65	23	26	4	3	4th
,, ♂	108	146	22	61	20	24	4	3	4th
,, ♂	93	134	21	58	21	22	4	3	4th
,, ♂	88	?	22	60	21	24	4	3	4th
,, ♂	93	137	21	61	21	23	4	4	3rd & 4th
,, ♂	92	162	22	64	21	26	4	3	4th
,, ♂	99	143	22	63	22	24	4	3	4th
,, ♀	86	102	20	54	20	21	4	3	4th
,, ♂	89	134	23	62	22	26	4	3	4th
,, ♀	75	?	18	50	18	21	4	4	4th
,, ♀	81	?	19	55	19	22	4	4	4th
,, ♀	75	103	18	54	18	22	4	3	4th
,, ♂	103	158	22	65	23	25	4	3	4th
,, ♂	106	?	24	67	24	25	4	4	4th
,, ♂	89	136	21	61	21	25	4	4	4th
,, ♂	99	?	22	61	22	24	4	3	4th
,, ♂	104	141	24	61	23	24	4	4	4th
,, ♂	96	?	23	65	23	25	4	4	4th
,, ♂	86	132	21	57	21	24	3	3	4th
,, ♀	81	112	19	54	19	22	4	3	3rd & 4th
,, ♀	93	116	21	58	21	21	4	4	4th
,, ♀	81	120	19	56	19	23	4	3	4th
,, ♀	66	92	18	49	17	19	3	3	4th
,, ♀	78	104	19	55	19	22	3·5	3·5	4th
,, ♀	75	106	18	54	18	21	3·5	3·5	4th
,, ♂	80	122	20	51	20	23	4	3	4th
,, ♀	81	99	19	48	18	19	4	4	4th
,, ♀	74	109	19	56	19	22	3·5	3·5	4th
,, ♀	71	91	18	47	17	21	3	3	4th
,, ♀	80	99	21	51	18	19	4	2·5	4th
Albrechts ♂	107	160	24	69	25	26	5	4	4th

* The course of the Nosob River between Ky Ky and its junction with the Molopo River.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
ALBANY MUSEUM:									
Fish River ♂	102	143	24	61	24	24	4	3	4th slightly
Cradock ♂	86	107	20	55	19	21	3	3	4th
Victoria West ♂	78	?	20	50	18	21	3·5	3·5	4th
,, ♂	85	?	20	55	19	22	3	3	4th slightly
,, ♂	99	119	24	61	23	23	4·5	3	4th
Beaufort West ♀	91	106	20	57	20	23	3·5	3·5	4th
Douglas ♂	75	?	20	56	20	23	4	3	4th
Kimberley ♂	89	121	22	56	21	21	4	3	4th
,, ♂	96	129	22	59	21	23	4·5	3	4th
,, ♀	82	?	20	57	20	22	3·5	3	4th
,, ♀	98	117	22	60	22	23	4	4	4th
,, ♀	83	103	19	54	20	21	3·5	3·5	4th
,, ♀	74	?	18	48	17	19	3	2	4th slightly
,, ♂	73	123	22	64	22	25	4	4	3rd & 4th
,, ♂	84	113	19	53	19	21	3·5	3·5	4th
,, ♂	107	138	24	62	23	23	4·5	3·5	4th
N.W. Gordonia ♂	100	154	24	66	24	25	5	4	4th
,, ♀	82	?	19	54	19	20	3·5	3	4th slightly
Rietfontein ♂	108	164	24	68	23	28	4	3	4th
,, ♂	107	165	23	68	24	27	4	4	4th
Ky Ky ♂	100	143	21	63	23	24	4	3	4th
,, ♂	94	146	23	65	22	25	4	3	4th
Grootfontein ♂	84	119	19	53	19	20	3	3	4th
S. AFRICAN MUSEUM:									
Ookiep ♂	102	152	24	67	24	26	4	4	3rd & 4th
,, ♀	97	105	23	65	22	27	4	4	4th
Pt. Nolloth ♂	104	136	20	63	25	25	4	2	4th
Burghersdorp ♀	83	94	21	55	20	22	4	3·5	4th
Neighb'hd. of Ludritzbucht ♂	97	137	22	61	21	23	4	2·5	4th slightly
,, ,, ♂	98	134	22	57	21	22	4	4	4th
,, ,, ♂	101	?	25	65	23	24	4	4	4th
,, ,, ♀	96	89	20	54	18	19	3	3	3rd & 4th
,, ,, ♀	90	98	20	37	20	22	4	4	4th
,, ,, ♀	87	?	20	60	26	22	3·5	3·5	3rd & 4th
,, ,, ♀	85	88	20	56	19	21	3	3	3rd & 4th
Gamis ♂	83	116	20	58	20	23	4	3	4th
Areb ♂	84	125	20	54	18	22	3	3	4th
,, ♂	96	157	23	63	23	24	4	3	4th
,, ♂	90	132	22	63	22	26	4	3	4th
Otyimbingue ♀	96	?	22	58	21	22	4	3	3rd & 4th
,, ♀	93	133	21	60	21	23	4	3	3rd & 4th
,, ♀	86	107	21	58	21	23	4	3·5	4th
,, ♀	92	123	22	62	22	23	4	3	4th
Nuragas, S.W. African Protectorate ♂	81	?	21	60	20	22	4	3	3rd & 4th
TRANSVAAL MUSEUM:									
Kimberley ♂	100	133	22	61	22	23	4	4	4th
,, ♂	106	138	24	66	24	25	4	3	4th

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Kimberley ♂	100	127	24	63	23	24	4	4	4th
,, ♂	78	89	19	53	19	22	3·5	3	4th
Plains near Wasserfall ♂	80	113	20	57	20	23	4	4	4th
,, ♀	103	?	22	61	22	23	4	4	4th
,, ♀	75	104	19	55	19	23	3·5	3·5	4th slightly
,, ♀	75	97	19	54	19	23	3·5	3·5	4th
,, ♂	79	?	20	56	20	24	3·5	3·5	4th
,, ♂	86	125	20	52	20	24	3·5	3·5	4th
Below Little Karas Mts. ♀	109	125	25	68	24·5	26	4·5	4	3rd & 4th
Sandmund, Gt. Karas ♀	95	110	21	59	21	23	4	3·5	3rd & 4th
Kraaikluft, Gt. Karas ♂	114	160	25	66	24	26	4	3·5	4th

The following discrepancies between various specimens and the above description are noted:

Enlarged dorsal scales in a fourth longitudinal series: De Aar ♀. Very few and but slightly enlarged, inclining towards *A. methueni*: Upington ♀, N.W. Gordonia ♀, Rietfontein 2 ♂, Grootfontein ♂. Scattered irregularly: Beaufort West ♀, Plains near Wasserfall ♀.

Small dorsal scales not mucronate except low down on the sides: Britstown, Upington, Ky Ky, Zwart Modder, and, in fact, nearly all the Kalahari examples.

Scales on upper surface of upper tibia very unequal: Britstown, Watersmeet, Dry Hart's River, Ky Ky, N.W. Gordonia, Kimberley.

Ventral scales feebly but distinctly keeled: Schoemansfontein, Jacobsdal Division, Kimberley, Daniel's Kuil, Taungs, Dry Hart's River, Genesa, Lower Nosop, Ky Ky, Beaufort West.

Head-scaling small, subconical in places, otherwise strongly keeled: Kimberley 5 ♂.

Parietal scale entirely absent: Albrechts ♂.

Preanal pores in two rows: 4 Kimberley, 1 Areb.

Hind limb reaching to the middle of the ear: Britstown ♂. Fifth toe extending as far as the first: Spreeuwfontein, O.F.S. ♂, Daniel's Kuil ♂, Dry Hart's River ♂, Ookiep ♂, Burghersdorp ♂, Lüdritzbucht ♂, Otyimbingue ♀ ♀, Plains near Wasserfall ♂, 3 ♀, Kraaikluft ♂.

Fifth toe extending beyond the first: Albrechts ♂.

Third and fourth toes equal on the right foot, fourth slightly the longer on the left: Kimberley ♂.

Third and fourth toes equal on left foot, fourth the longer on the right: Kimberley ♀, Genesa ♀.

Toes short and thick: Kimberley ♀, Grootfontein ♂, Lüdritzbucht ♂.

Feet abnormally long and slender: Douglas ♂, Burghersdorp ♀, Gamis ♂, Otyimbingue 2 ♀, Plains near Wasserfall 3 ♀, 2 ♂.

Head longer than broad: Daniel's Kuil ♂, Otyimbingue 2 ♀, Plains near Wasserfall ♀ ♂

Eye-cleft and ear equal on the right side, unequal on the left: Ky Ky ♂ ♀, Spreeuwfontein, O.F.S. ♂.

The following unusual combinations of characters are noticed in individual specimens:

Britstown ♂. Scaling on upper surface of tibia very unequal (as in typical *A. distanti*); adpressed hind limb reaching the middle of the ear-opening; small dorsal scaling not mucronate.

A young from Schoemansfontein, O.F.S. (about 30 miles S.E. of Kimberley) has the dorsal scaling like specimens from Bloemfontein, the fourth toe longest and the fifth extending well beyond the first. Ventral scales feebly keeled.

Kimberley ♀. This specimen differs very much from the description given at the beginning. The toes short and thick, enlarged dorsals very much enlarged, ventral scales feebly but distinctly keeled, scales on upper surface of tibia unequal. Third toe the longest.

Kimberley ♀. Third and fourth toes equal on the left foot, the fourth longer on the right foot; scaling as in *A. distanti*.

Kimberley ♂. Toes very short and thick; tail unusually short for a ♂; preanal pores in two rows.

Kimberley ♀. Agrees with the description of *A. distanti* in every respect save that the scales on the upper surface of the tibia are equal.

Six specimens from Daniel's Kuil exhibit the following characters A ♂ has enlarged dorsal scales arranged in three clusters on three dark brown patches at either side of the vertebral line, a very distinct dorsal crest extending the full length of the tail; scales on upper surface of tibia unequal. The colour on the ventral surface of this specimen is very peculiar, there being broad red wavy lines forming a large-meshed network on the whole surface, especially on the chest; longitudinal cobalt-blue lines under the head, throat blue-black; head slightly longer than broad. A ♂. Scaling the same as in the preceding but enlarged dorsal scales much smaller, scales on tibia subequal; fifth toe does not extend quite as far as the first.

A ♂. Enlarged dorsal scales arranged in three more or less longitudinal series on either side; reddish brown network ventrally.

A ♂. Dorsal scaling as in first specimen; scales on tibia equal.

A ♀. Scaling as in first specimen; ventral scales feebly keeled.

A ♀. Ventral scales keeled on the chest, otherwise typical.

Taungs, ♀. Head as broad as long; dorsal scaling and feet as in typical *A. armata*; ventral scales feebly keeled; scales on upper portion of left tibia very unequal, equal on the right; fourth toe longest.

Watersmeet, Vryburg, ♀. Head-scales very strongly keeled throughout as in typical *A. distanti*; scales on upper portion of tibia very unequal; ventrals strongly keeled throughout, strongly mucronate on the abdomen

and at the sides; occipital scale very much enlarged; fifth toe not extending as far as the first, fourth the longest.

Dry Hart's River, ♂. Dorsal and head scaling as in typical *A. distanti*; scales on tibia very unequal; ventrals feebly but distinctly keeled, fifth toe does not extend nearly as far as the first, fourth toe the longest.

Genesa, ♀. Third and fourth toes equal on the left foot, fourth the longer on the right.

Genesa, ♀. Head and body scaling as in *A. anchietae*; ventral scales feebly keeled throughout, feet long and slender, fourth toe the longest.

Genesa, ♀. Head slightly longer than broad, scales thereon keeled; toes very long and slender; dorsal scaling the same as in specimens from Mariannhill; ventrals smooth.

Ky Ky, ♀. Enlarged dorsals very few and only slightly enlarged; small scales not mucronate except low down on the sides. This applies to several specimens from Ky Ky and neighbourhood.

Ky Ky, ♀. Scales on upper tibia very unequal; enlarged dorsals in groups somewhat like certain specimens from Pretoria; head-scales very rough. This specimen seems quite close to *A. brachyura*, the ear-opening is 3·5 mm. on the right side, 2·5 mm. on the left side.

Reitfontein, ♂. Dorsal scaling and head-scaling as in *A. methueni*; enlarged dorsal scales very few and scattered irregularly, smaller ones keeled but not mucronate; tail rounded.

Ookiep, ♂. On plateau. Scaling throughout as in Kalahari specimens; tail laterally compressed, toes long and slender, fifth not extending quite as far as the first; scaling on tail in distinct whorls.

Pt. Nolloth, ♂. This was at first placed as *A. brachyura* but on further consideration it was transferred to *A. aculeata*, though the ear-opening (2 mm.) is rather smaller than is usual in the latter species; fifth toe extending as far as the first.

Lüdritzbucht, ♂. Dorsal scaling between *A. methueni* and *A. aculeata*, no trace of a dorsal crest; ear opening rather small.

Lüdritzbucht, ♂. Toes rather short and thick, fifth not extending quite as far as the first; scaling like that of Gordonia specimens.

Lüdritz, ♀. Dorsal scaling as in *A. aculeata* (typical); head-scales very unequal; head longer than broad, ventrals feebly but distinctly keeled.

Areb, ♂. Larger dorsal scales only very slightly enlarged, resembling *A. methueni*; head much longer than broad, scales thereon strongly keeled; ventrals feebly but distinctly keeled on the chest, under the head and on the sides of the abdomen.

Wasserfall, six specimens as follows: (1) ♂. Toes fairly long and slender, fifth not reaching first. Head only slightly longer than broad, scaling not unlike that of *A. methueni*. (2) ♀. Head much longer than broad, enlarged dorsals scattered, not forming a regular longitudinal series,

adpressed hind limb reaching well beyond the ear, toes long and slender, fifth extending beyond the first. (3) ♀. Feet very long and slender, fifth not extending quite as far as the first, head as long as broad. (4) ♂. Toes very long and slender, head slightly longer than broad. (5) ♂. Head as long as broad, feet and toes very long and slender. (6) ♀. Enlarged dorsals only slightly so and in 3 longitudinal series on either side. Toes very long and slender, fifth not extending as far as the first.

Kraaikluft, ♂. Toes moderately long, fifth not extending as far as the first, enlarged dorsals few.

Beaufort West, ♀. Enlarged dorsals scattered irregularly, not in longitudinal rows.

Gt. Namaqualand. Several ♂♂ show a rather gradual change from *A. aculeata* to *A. methueni*, some of them resembling *A. methueni* in dorsal scaling, others *A. aculeata*.

Victoria West, ♂. Dorsal scaling as in Kimberley specimens; head-scales very strongly keeled, subconical on the occiput; enlarged dorsals continued for a short distance on the tail.

There is scarcely any doubt that the specimens examined by us from the neighbourhood of Port Nolloth, which we are referring to this variety, link it up with *A. brachyura*; and those from the country round Kimberley and between it and Mafeking connect *A. aculeata* and *A. distanti*.

This *Agama* in the neighbourhood of Kimberley lives on the open veld, where it may be seen on stones, on the tops of wooden fence-posts or poised on the tops of thorn trees.

In winter it hibernates in holes, under stones and tins or in deserted termite heaps.

Like the typical *A. hispida* it is partly herbivorous, partly insectivorous.*

E. Var. ARMATA.

Agama armata, Peters, Mon. Berl. Ac. 1854, p. 616, and Reise n. Mossamb. iii, p. 42, pl. vii, fig. 2 (1882); Bouleng. Cat. Liz. i, p. 352 (1885).

We have no doubt as to the correct application of this term, the lizard having been carefully described and figured by Peters from specimens obtained by him in the interior of Portuguese East Africa, south of the Zambesi (Sena and Tetta). It is an Eastern form extending southwards to Natal.

Form.—Habit less stout than in the preceding, body usually less depressed. Head convex, longer than broad; snout short, rounded; canthus rostralis very short; nostril directed outwards, in a convex but not tubular

* For further particulars regarding life-history, etc., see Trans. Roy. Soc. South Africa, iii, pp. 151, 152; Rep. South African Assoc. Adv. Sci., 1917, p. 263.

shield, pierced just below the canthus rostralis; length of head $3\frac{3}{4}$ to $4\frac{1}{6}$ times in length to vent. Diameter of ear-opening equal to or a little less than cleft of closed eye (rarely only $\frac{2}{3}$). Limbs short or moderately elongate; the hind limb, pressed against the body, reaches the shoulder, the neck, the ear, or the temple; length of hand greater than depth of head; fingers more slender than in the preceding, third or third and fourth longest; tibia as long as or shorter than the head or the foot; toes longer and more slender than in the preceding, third and fourth equal, or third or fourth slightly the longer, fifth extending as far as first or slightly beyond, exceptionally not so far. Tail cylindrical, moderately slender, longer ($1\frac{1}{9}$ to $1\frac{3}{5}$) than head and body, rarely a little shorter (♀); sometimes very slender in ♀.

Measurements:

	1.	2.	3.	4.
Snout to vent	67	66	84	77
Head	18	17	21	20
Width of head	17	15	18	17
Depth of head	11	10	12	12
Diameter of eye-cleft	3·5	3	4	4
„ ear-opening	3·5	3	4	4
Fore limb	31	31	36	35
Hand	12	12	15	14
Hind limb	45	46	52	44
Tibia	15	15	19	14
Foot	17	19	19	16
Tail	89	96	93	90

1. ♂, Natal. 2. ♂, Klukluwe, Zululand. 3. ♀, Gazaland, P.E.A. 4. ♀, Natal.

Lepidosis.—Upper parts, as a rule, not so rough as in the preceding; scales strongly keeled and usually shortly mucronate, the larger ones strongly mucronate, and arranged in three longitudinal series on each side of the back, exceptionally more irregularly distributed; 73 to 95 scales round the middle of the body*; the largest spinose scales near the ear-opening much shorter than the diameter of the latter; vertebral crest very low on the nape, more or less distinct on the back. Upper head-scales unequal, keeled, 2 to 4 on the middle of the snout more or less enlarged; occipital enlarged; 12 to 16 scales across the head from one superciliary series to the other; 10 to 13 upper labials on each side; 3 or 4 series of scales between the upper labials and the nasal. Gular and ventral scales usually keeled and mucronate, even strongly, but sometimes smooth or feebly keeled. Caudal scales strongly keeled and mucronate, not forming whorls, equal except at the base. Scales on upper surface of tibia subequal in size, rarely unequal.

* 80 to 86 in the types according to Peters.

14 to 20 scales under the 3rd or 4th toe. Male with a single or double row of rather small preanal pores.

Coloration.—Yellowish or greyish brown to dark brown above, the vertebral region sometimes lighter, uniform, or with 4 or 5 transverse series of dark spots on the body; some of the larger scales carmine (♀, Gazaland); head sometimes blackish above and bluish on the sides (♂, Natal, ♀, Gazaland); limbs and tail usually with more or less distinct dark cross-bars. Lower parts whitish, throat usually with bluish-grey or blackish wavy longitudinal lines; traces of a dark network sometimes present on the belly.

Particulars of Specimens Examined.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
BRITISH MUSEUM:									
Gazaland, Portug. E. Africa ♀	84	93	21	52	19	19	4	4	3rd
Lourenço Marques .. ♀	57	63	16	42	14	17	3	2·5	3rd
Delagoa Bay ♂	65	88	17	45	15	17	3·5	3	3rd
Kluhluhe, Zululand ♂ . .	66	96	17	46	15	19	3·5	3	4th
„ „ ♂ . .	59	92	16	44	14	19	3	2·5	4th
Zululand ♀	75	99	18	50	16	19	4	3·5	3rd & 4th
Natal (Warren) ♂ . . .	67	89	17	45	15	17	3·5	3	3rd
„ (Gurney) ♀ . . .	77	90	20	44	14	16	4	4	3rd
BULAWAYO MUSEUM:									
Mariannhill ♂	60	89	18	37	13	17	3	2	3rd & 4th
Bulawayo ♂	74	106	16·5	49	16·5	20	4	3	3rd
„ ♂	73	97	17	49	16	16	3	3	3rd
„ ♂	63	78	15	40	14	16	3	3	3rd
„ ♂	71	?	16	48	16	19	3	3	3rd
„ ♀	64	75	16	40	13	17	3	3	3rd & 4th
„ ♀	66	80	16	46	15	17	3	3	3rd
„ ♂	74	117	17	51	17	21	3	3	3rd
„ ♂	80	90	18	47	16	18	3	3	3rd & 4th
„ ♂	65	73	15	44	15	16	3	3	3rd
„ ♂	70	95	17	48	16	18	3	3	3rd
„ ♂	67	80	17	47	15	18	3	3	3rd
„ ♂	84	111	18	56	18	21	3	3	3rd
„ ♂	83	101	18	50	17	19	3	3	3rd
„ ♀	77	69	17	46	16	17	3	3	3rd
„ ♂	74	96	16	45	16	19	3	3	3rd
„ ♂	64	86	16	25	15	17	3	3	3rd
„ ♂	89	118	19	54	19	20	3·5	3·5	3rd
„ ♂	85	118	19	51	18	20	3	3	3rd
„ ♂	95	118	20	56	20	22	3·5	3	3rd
„ ♀	87	89	16·5	52	16	19	3	3	3rd & 4th
„ ♀	65	80	20	43	14	17	3	3	3rd & 4th
„ ♂	71	92	16	43	15	17	3	3	3rd
„ ♀	71	88	17	46	16	18	3	3	3rd
N. Rhodesia ♀	80	79	18	49	18	19	3	3·5	3rd
Rhodesia ♂	64	92	20	43	15	18	3	2	3rd & 4th

	1.	2.	3.	4.	5.	6.	7.	8.	9.
NATAL MUSEUM:									
Natal ♂	53	69	15	36	11	14	2·5	2	4th slightly
Entendweni, Zululand ♂ .	55	89	18	44	13	18	3	2·5	4th
KIMBERLEY MUSEUM:									
Mariannhill ♀ . . .	57	?	14	40	13	17	3	2·4	3rd & 4th
,, ♂ . . .	57	81	14	37	13	15	3	2·5	3rd & 4th
Rikatla ♀	73	82	17	47	17	18	3	3	3rd
,, ♀	80	86	18	47	16	17	3	2·5	3rd
,, ♀	61	83	15	47	16	19	3	2·5	3rd
Serowe ♂	78	?	19	50	18	18	3	3	3rd
Plumtree ♂	73	93	18	51	18	20	3	3	3rd
,, ♂	64	78	16	44	15	17	3	3	3rd
Buluwayo ♂	54	70	16	38	14	15	3	3	3rd
,, ♀	62	86	19	45	16	17	3	3	3rd
,, ♂	75	?	23	64	15	18	3	3	3rd
Marandellas ♂ . . .	66	84	16	40	14	17	3	3	3rd
Salisbury ♀	75	70	17	43	15	17	3	3	3rd
ALBANY MUSEUM:									
Mariannhill ♀ . . .	75	79	18	43	15	16	3	2·5	3rd
,, ♀	70	79	16	43	16	17	3	2	3rd
,, ♀	64	?	14	38	13	16	3	2·5	3rd
,, ♂	56	?	17	39	13	16	2·5	2·5	3rd & 4th
,, ♂	51	75	13	34	11	15	2·5	2	3rd & 4th
,, ♂	50	68	12	32	12	14	2	2	3rd & 4th
,, ♂	48	62	13	32	12	15	2·5	2·5	3rd
Kwambonambi ♀ . . .	67	102	15	46	15	20	3	2·5	4th slightly
Wastdale, Rankin's Pass ♀ .	75	81	18	47	17	18	3	3	3rd
,, ,, ♀ .	68	77	16	41	16	17	3	2·5	3rd
White River ♀ . . .	66	66	16	41	14	16	3	3	3rd
,, ♀	74	?	17	41	16	16	3	3	3rd
Serowe ♀	81	93	18	46	17	18	3	3	3rd
Bulawayo ♂	86	114	19	50	18	20	3·5	3	3rd
Salisbury ♂	44	?	14	28	9	11	2	2	3rd & 4th
TRANSVAAL MUSEUM:									
Weenen, ♂	70	98	17	49	16	20	3	3	3rd & 4th
Indukuduku, Zululand ♀ .	64	95	15	47	15	20	3	2·5	3rd slightly
,, ,, ♂ .	60	84	15	40	13	16	3	2	3rd
,, ,, ♂ .	61	85	15	42	14	17	3	2	3rd & 4th
Pretoria Zoo ♂ . . .	68	86	16	47	16	18	3	2	3rd
Krantz View, Carolina ♂ .	70	80	17	44	14	16	3	3	3rd
Barberton ♀	73	66	16	43	14	17	3·5	3	3rd
Vygeboompoort ♀ . . .	71	?	17	46	14	18	3	3	3rd
,, ♂ . . .	61	77	16	42	13	17	3·5	3	3rd
,, ♂ . . .	69	98	17	47	15	18	3·5	2·5	3rd
,, ♀ . . .	81	77	18	46	15	16	3	3	3rd
,, ♂ . . .	71	99	17	42	15	17	4	3	3rd
,, ♂ . . .	63	73	15	39	14	16	3	3	3rd
Lydenburgh Kranz ♀ . .	56	70	15	42	15	17	4	3	3rd
Great Letaba River ♀ . .	66	55	15	39	13	15	3·5	3·5	3rd

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Mazambo ♂	50	78	14	39	13·5	16	3	2	3rd
„ ♀	46	63	13	36	12	16	2.5	2	3rd
Transvaal ♀	73	70	17	46	15	17	3	3	3rd
Griffin Mine, Leydsdorp ♂	62	93	15	39	14	16	3	3	3rd slightly
„ „ ♀	76	81	17	45	15	17	3	3	3rd
Bulawayo ♀	87	85	19	51	18	19	4	3	3rd & 4th
South African Museum:									
Natal ♀	60	76	15	42	14	17	3	3	3rd & 4th
Delagoa Bay ♂	74	?	19	50	18	19	4	3	3rd
Bulawayo ♂	87	125	18	51	18	21	4	3	3rd
„ ♀	84	79	19	49	17	18	4	4	3rd
Livingstone ♀	74	71	17	41	14	16	3	3	3rd slightly
„ ♀	76	78	16	43	15	16	3	3	3rd
Salisbury ♀	74	65	16	41	14	16	3	3	3rd slightly
„ ♀	77	?	18	48	17	18	3	3	3rd slightly
„ ♀	73	61	16	40	14	15	3	3	3rd
Schishawasha ♀	68	84	17	45	16	17	3	3	3rd slightly
„ ♀	77	60	18	41	15	16	3	3	3rd
„ ♂	76	?	20	46	16	17	4	3	3rd & 4th
„ ♂	72	?	19	44	16	17	3·5	3	3rd & 4th
„ ♂	77	99	18	46	17	17	3·5	3	3rd
„ ♀	74	66	17	42	15	17	3	3	3rd
„ ♀	72	73	17	42	16	18	3	3	3rd

Specimens differing from the foregoing description are as follows:

Enlarged dorsal scales in 2 longitudinal series on the sides: Plumtree ♂.

Scales on upper surface of tibia very unequal: Plumtree, ♂, Mariannhill, 3 ♀, Mazambo, ♀, Bulawayo, ♀, 2 ♂; Lydenburg Kranz, ♀.

Dorsal scaling like specimens of *A. distanti* from Pretoria: Plumtree, ♂, Bulawayo, ♀.

Preanal pores in 2 rows: Marandellas, Bulawayo, 2.

Fifth toe not extending as far as the first: Serowe, ♀, N. Rhodesia, ♀, Indukuduku, ♀, Pretoria Zoo, ♂, Lydenburg Kranz, ♀, Mazambo, ♀, Griffin Mine, Leydsdorp, ♂, Bulawayo, ♂, 2 ♀.

The following combinations of characters may be noted:

Mariannhill, ♀. Enlarged dorsal scales in 3 longitudinal series on either side of the vertebral line and carried on to the tail for about ¼ of its length; scales on upper surface of tibia unequal; head-scales very rough, spinose scales at sides thereof very few and short; toes very long and slender; tail very slender, thick at the vent, then tapering suddenly; keels on caudal scaling forming longitudinal ridges.

Marandellas, ♂. Scarcely to be distinguished from the Mariannhill specimens; a second row of small preanal pores. All the young resemble those from Mariannhill in scaling, head characters and feet, except one, in which the head is as broad as long.

Eldorado, ♂. A young is just like the Mariannhill ones, except that the enlarged dorsal scales are only very slightly so.

Salisbury, ♀. Ventral scales feebly keeled throughout, but not mucronate; spinose scales on the sides of the head and neck very few and very short.

Giant's Castle, Natal. This specimen is damaged; dorsal scaling resembling that of *A. anchietae*, scarcely any enlarged ones; ventrals feebly keeled, not mucronate; no dorsal crest whatever; all head-scales more or less subconical; head slightly longer than broad; fifth toe extending as far as the first.

Lydenburg Kranz, ♀. Toes only moderately slender, fifth not extending as far as the first; head slightly broader than long; dorsal scaling as in typical *A. armata*; scales on upper surface of tibia very unequal; ventral scales strongly keeled.

Owing to the many discrepancies in specimens from Bulawayo and neighbourhood, it is advisable to give detailed notes on the individuals. In nearly all of them the head is longer than broad, and since this character is of more importance than the scaling, which shows such a wide range of variation, all these specimens are placed with *A. armata*.* In scaling and general appearance the specimens from Bulawayo and Plumtree resemble *A. aculeata*.

Bulawayo, ♀. Head-scales very strongly keeled; dorsal scaling as in *A. distanti*; fifth toe not reaching as far as the first; scales on upper surface of tibia unequal; ventrals feebly keeled on the chest; head much longer than broad.

Bulawayo, ♂.—Dorsal scaling as in *A. aculeata* from the Kalahari; toes fairly slender, fifth not extending as far as the first; ventral scales smooth; nuchal but no dorsal crest.

Bulawayo, ♂. Dorsal scaling like that of *A. aculeata* from Kalahari; toes long and fairly slender, fifth extending as far as the first; ventral scales smooth; nuchal but no dorsal crest.

Bulawayo, ♂. Dorsal scaling resembling that of specimens of *A. aculeata* from Kimberley; scales on upper surface of tibia unequal; toes long and fairly slender, fifth extending as far as the first; head longer than broad.

Bulawayo, ♂. Head much longer than broad; toes fairly short and thick, fifth reaching as far as the first.

Bulawayo, ♂. Dorsal scaling as in *A. aculeata*; toes long and fairly slender, fifth extending as far as the first; head longer than broad: scales on upper surface of tibia unequal.

* Of the specimens from Bulawayo and the neighbouring districts, 83 per cent. have the head longer than broad, 12 per cent. as long as broad, 4 per cent. broader than long; 45 per cent. have the 5th toe not extending as far as the 1st, 21 per cent. extending beyond the 1st, 33 per cent. extending as far as the 1st.

Bulawayo, ♀. Like *A. armata*, but the ventral scales are smooth.

Bulawayo, ♂. Toes long and slender, fifth extending as far as the first; head as long as broad. Otherwise like *A. distanti*.

Bulawayo, ♂. Dorsal scaling as in *A. aculeata*, from Kimberley; scales on upper surface of tibia unequal; toes long and fairly slender, third longest on the left foot, fourth slightly the longest on the right, fifth extending as far as the first; head longer than broad.

Bulawayo, ♂. Head much longer than broad; toes fairly short and thick, fifth reaching as far as the first.

Bulawayo, ♂. Dorsal scaling as in *A. aculeata;* toes long and fairly slender, fifth extending as far as the first; head longer than broad; scales on right tibia very unequal, equal on the left.

Bulawayo, ♂. Resembles *A. distanti* in every particular; but preanal pores in two rows.

Bulawayo, ♀. Like *A. armata* in all respects.

Bulawayo, ♂. Resembles *A. armata* in the character of the dorsal scaling and head; scales on upper surface of tibia very unequal.

Bulawayo, ♀. Head rather sharp-pointed; toes long and slender, fifth not extending as far as the first.

Bulawayo, ♀. Dorsal scaling as in typical *A. distanti;* scales on upper surface of tibia equal.

Bulawayo, ♂. Same as *A. armata* in every respect save that the ventrals are smooth.

Bulawayo, ♂. Scaling as in *A. distanti*, otherwise (head, toes, etc.) as in *A. armata*.

Bulawayo, ♂. Typical *A. armata;* ventrals smooth.

Bulawayo, ♂. Scales on upper tibia unequal; head as long as broad, scaling and general appearance as in *A. aculeata;* preanal pores in 2 rows.

Bulawayo, ♂. Scaling, etc., as in *A. aculeata;* head as long as broad.

Bulawayo, ♂. Exactly like *A. armata;* scales on upper tibia very unequal; ventrals feebly keeled.

Bulawayo, ♂. Head-scales very strongly keeled, subconical round the occipital and on the head over the ears; scaling otherwise as in *aculeata*.

Bulawayo, ♂. Resembles *A. armata* in dorsal scaling and head, but the scales on the upper surface of the tibia are very unequal.

Bulawayo, ♂. Scales on upper tibia unequal; head as long as broad; scaling and general appearance like *A. aculeata*; preanal pores in two rows.

Plumtree, ♂. The enlarged dorsal scales in two longitudinal series; toes very long and slender, fifth extending slightly beyond the first; scales on upper surface of tibia very unequal; scaling generally not quite so rough as in some females from Mariannhill.

Plumtree, ♂. Head-scales very strongly keeled, having a decidedly granular appearance; dorsal scaling as in *A. distanti*; fifth toe extending as

far as the first; ventral scales smooth; scales on upper surface of tibia very unequal.

Mazambo, ♀. Fifth toe not extending as far as the first; head as broad as long; scales on upper surface of tibia very unequal; dorsal scaling somewhat resembling *A. distanti*; toes very long and slender; ventrals strongly keeled and mucronate.

Serowe, ♀. Exactly like specimens from Mariannhill as regards scaling and head, but the fifth toe does not extend quite as far as the first.

Mozambo, ♂. Ventral scales smooth, otherwise typical.

Griffin Mine, Lydsdorp, ♂. Head much longer than broad; dorsal scaling as in those from Mariannhill; toes long and slender, fifth not reaching as far as the first; scales on upper surface of tibia very unequal; ventrals feebly keeled.

2. Agama anchietae.

A. *Forma typica.*

Agama, sp., Bocage, Herp. Angola, p. 21 (1895).

Agama anchietae, Bocage, Jorn. Sc. Lisb. (2) iv, 1896, p. 129.

Form.—Body moderately depressed. Head convex, as long as broad; snout very short, rounded; canthus rostralis very short; nostrils directed upwards and outwards or nearly straight upwards, in a very convex, subtubular shield pierced on or just above the canthus rostralis; length of head about 4 times in length to vent. Diameter of ear-opening equal to or slightly less than cleft of closed eye. Limbs moderately elongate; the hind limb, pressed against the body, reaching the neck or the ear; length of hand equal to or a little less than depth of head; fingers and toes short, not or but feebly compressed; third toe slightly longer than fourth, fifth extending as far as first or a little farther; tibia as long as head or a little longer or a little shorter, foot considerably shorter. Tail cylindrical in females, feebly compressed in males, longer ($1\frac{1}{8}$ to $1\frac{1}{3}$ times) than head and body.

Measurements (in millimetres):

	1.	2.	3.	4.	5.
From snout to vent	80	80	84	84	81
Head	20	20	22	21	20
Width of head	20	20	22	21	20
Depth of head	13	13	15	14	14
Diameter of eye-cleft	4	4	4	4	4
„ „ ear-opening	4	3·5	4	4	3·5
Fore-limb	44	42	42	42	39
Hand	13	13	13	14	13
Hind limb	57	55	56	56	51
Tibia	22	21	22	21	19
Foot	18	17	18	18	17
Tail	105	90	109	109	?

1. ♂, Maconjo, Angola. 2. ♀, Caconda, Angola (type). 3. ♀, Caconda. 4. ♀, Goas, Namaqualand (S.A. Museum). 5. ♀, Matahöle, Namaqualand (S.A. Museum).

Lepidosis.—Upper parts with strongly keeled scales, some of which may be mucronate, with few or moderately numerous, irregularly scattered enlarged ones, the mucronate or spinous character of which is more pronounced; lateral scales pointing towards the vertebral line; groups of spinose scales on the side of the neck and behind the ear-opening, the largest much shorter than the diameter of the latter; a low nuchal crest, continued along the back as a series of slightly enlarged, more strongly keeled scales; 90 to 100 scales round the body. Upper head-scales smooth or obtusely keeled, 10 to 14 across from one superciliary series to the other; occipital scale moderately or feebly enlarged (larger in the young); 11 to 14 upper labials on each side; 3 to 5 series of scales between the upper labials and the nasal. Gular and ventral scales more or less distinctly keeled, not or but feebly mucronate, except on the sides. Scales on upper surface of limbs equal; scale at the base of the claw, on the dorsal surface of the toes, tricarinate and much longer than the others; subdigital scales extremely spinose, the tips of the spines often dark brown or black, 13 to 16 in a longitudinal series under the third toe. Caudal scales strongly keeled, not forming whorls, subequal in size; the vertebral series forming a low serrated edge or crest.

Male with a single series of rather large preanal pores.

Coloration.—Pale yellowish or greyish brown above, uniform, or with 4 or 5 pairs of dark spots or wavy cross-bands on the body, separated by a vertebral series of pale oval or rhombic spots or by a yellow vertebral band; limbs and tail with more or less distinct dark cross-bands. Lower parts white, throat usually with wavy dark longitudinal lines; male with a central dark patch on the throat.

Habitat.—Angola and Namaqualand. The British Museum collection contains, in addition to two specimens (from Caconda and Catumbella) received from the late Prof. Barboza du Bocage, several obtained in Benguella (Caconda, Catumbella, Maconja, Huxe, Cuangu) by Dr. Ansorge. We have also examined specimens from Namaqualand (Goas, Matahöle) in the South African Museum.

B. Var. METHUENI, var. nov.

Agama aculeata, part., *A. atra*, part., Methuen and Hewitt, Ann. Transv. Mus. iv, 1914, p. 136.

"Four specimens [from S.W. Africa] are noteworthy owing to the fact that the dorsal crest is practically obsolete on the back; moreover, the enlarged tubercles are not numerous and arranged in an irregular fashion

such as is often met with in *A. atra*; these might be confounded with the latter species, from which they are distinct, however, in the length of the toes." (Methuen and Hewitt, *l.c.*)

We have examined these specimens (Gt. Karas Mts.) and a few others from the S. African Museum (Voigtsgrund, S.W. Africa, Namaqualand and Naroep, Namaqualand), also two in the Kimberley Museum (found between Zwart Modder and Rietfontein), and find they represent an undescribed form, which we regard as a variety of *A. anchietae*.

The shape and proportions are the same as in the typical form,* and it may suffice to mention that the hind limb reaches the ear or just behind it, that the toes are either short or moderately elongate, and that the foot is as long as or a little shorter than the tibia. Tail compressed and crested in the males, longer ($1\frac{1}{8}$ to $1\frac{1}{2}$ times) than head and body; rounded or nearly so in the females.

Scales on head, body and limbs as in the typical form,† except that the vertebral crest, which is slight on the nape, is absent on the back, and reappears on the tail, in males at least, where it forms a low serrated ridge; 90 to 105 scales round middle of body. Gular and ventral scales smooth or feebly keeled, sometimes rather strongly keeled and mucronate on the abdomen and on the sides. 14 to 17 scales in a longitudinal series under the third toe.

Dark brown above, with lighter transverse markings on the vertebral line, or reddish brown, grey or yellow, with dark brown, dark grey, or red zigzag transverse bands. A large female from Naroep is bright yellow, with small cream-coloured spots and larger orange spots, the head blackish with small light spots. Lower parts white, the head with a bluish or blackish network; belly sometimes with bluish vermiculations.

Particulars of Specimens Examined.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
British Museum:									
Great Karas Mts. ♂	74	92	19	52	20	18	7	3·5	3rd
Naroep Namaland ♀	93	122	22	65	23	22	4	4	3rd
Namaqualand ♀	80	118	20	62	21	21	4	3·5	3rd
Kimberley Museum:									
Zwart Modder-Rietfontein ♂	86	130	22	60	22	20	4·5	3·5	3rd
Ditto ♂	87	100	22	56	21	21	5	4	3rd (R.), 4th (L.)
South African Museum:									
Voigtsgrund, Namaland ♂	91	115	23	62	22	20	4·5	3·5	3rd

* Some specimens show a very pronounced depression on the forehead between the eyes, but this feature has also been observed in specimens of the typical form by Bocage: "Une dépression plus marquée entre les orbites."

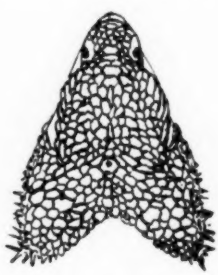
† In a male from Voigtsgrund the occipital scale is entirely absent.

		1.	2.	3.	4.	5.	6.	7.	8.	9.
TRANSVAAL MUSEUM:										
Great Karas Mts.	♀ .	92	107	21	55	21	18	4	3	3rd
"	♀ .	91	104	20	54	20	18	4	3	3rd
"	♀ .	87	108	21	55	20·5	19	4	4	3rd
"	♀ .	83	107	19	51	21	19	4	3·5	3rd

c. Var. KNOBELI, var. nov.

This name is proposed for specimens from Aus in Namaqualand, which had previously been confounded with *A. atra.*

The male is readily distinguished by a very peculiar physiognomy, due to the shape of the head, which is considerably longer than broad and much



A. knobeli. Head of male.

less depressed than in *A. atra* ; snout rather pointed, with the sides nearly vertical; cleft of the eye shorter than the very large ear-opening, though sometimes but very slightly. A small gular pouch is present. Body much flattened; tail very strongly compressed, fully twice, often three times, as deep as broad and tapering suddenly to a point. Limbs strong and similar to those of *A. atra* ; the hind limb, stretched forward, reaches the neck or the ear; tibia longer than the head and as long as, or a little longer or a little shorter than, the foot; toes compressed distally, fifth extending a little farther than first, third and fourth equal or fourth the longer.

The scaling suggests *A. atra*, but the lateral scales point obliquely inward, as in *A. hispida* and *A. anchietae.* Scales on the head rather large and smooth, except just behind the ear, where they are rather strongly keeled, 12 to 14 in a transverse series from one superciliary to the other; occipital very feebly enlarged; 12 to 14 upper labials; 2 or 3 series of scales between the labials and the nasal, which is convex; nostril pierced on the canthus rostralis and directed backwards in the posterior half of the nasal; very short spines near the ear. Scales on body small, 134 to 143 round the middle; dorsals smooth or keeled, some obtuse behind, others shortly mucronate, and graduating into the much smaller laterals; a few slightly

enlarged, spinose scales irregularly scattered on the back; ventral scales generally smaller than the dorsals, smooth. A feeble nuchal crest, continued on the anterior half of the body, then gradually lost, and reappearing on the tail, where it is very strongly developed. Caudal scales not forming distinct whorls, rather feebly keeled, some denticulated or mucronate. Scales on upper surface of tibia moderately large and subequal, strongly keeled.

A single series of large preanal pores; two series in one specimen.

The female could be easily mistaken for *A. atra*, with which it agrees in the shape and strong depression of the head * and in the proportions of the body and limbs; the tail is feebly or scarcely compressed and longer than head and body.

The scaling differs from that of the male in the following unimportant points: 11 scales from one superciliary to the other; 11 to 13 upper labials; scales on back and sides distinctly keeled, none enlarged; crest merely indicated on the nape, absent on the back and tail; 125 scales round middle of body.

In some of the specimens the spines on the plantar and subdigital scales are dark at the tip.

Greyish above, with the vertebral region lighter, yellowish, and faint traces of 4 or 5 darker blotches on each side of the back, which is speckled with black; the enlarged scales (male) whitish; head with dark wavy lines; a curved blackish line, or a blotch, along each side of the nape in males; upper surface of tail with dark transverse blotches. Whitish beneath, sometimes with dark bluish vermiculations, the middle of the throat blue; a wide-meshed blackish network on the head, more distinct in males, or males with the throat cobalt blue with black wavy longitudinal lines.

The following details regarding the colours in life have been supplied by Capt. J. B. Knobel, who collected the specimens, and after whom this new variety is named:

"They can change their colour like chameleons. I have killed one of various fiery-tan or terra-cotta and grey mixtures when lying on a stone, and when I took it from my pocket later it was dark blue and lighter blue. Some are dark ultramarine blue on the head and throat, Oxford blue on the chest and belly, and Cambridge blue on the flanks. At other times the whole head and body are very deep blue."

Measurements (in millimetres):

	1	2
	♂	♀
From snout to vent	126	108
Head	28	24

* More convex in one of the specimens examined, the length, width and depth being 21, 15 and 13 mm. respectively, instead of 24, 24 and 13.

	1	2
Width of head	24	24
Depth of head	18	13
Eye-cleft	5	4
Ear-opening	6	5
Fore limb	57	52
Hand	22	20
Hind limb	89	73
Tibia	32	27
Foot	32	27

1. Aus. 2. Aus, S.W.A. types.

Particulars of Specimens Examined.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
KIMBERLEY MUSEUM:									
♂	126	?	28	89	32	32	5	6	4th
♂	123	127	27	72	27	27	4	5·5	4th
♂	109	146	26	72	27	27	4	4·5	3rd & 4th
♂	100	?	23	68	26	24	4	5	4th
♂	99	134	25	78	27	28	4	5	4th
♂	92	?	23	65	24	24	4	4·5	4th
♀	108	125	24	73	27	27	4	5	3rd & 4th
TRANSVAAL MUSEUM:									
♂	·123	161	29	76	28	27	5	5·5	4th
♂	111	140	26	75	27	26	4·5	5	4th
S. AFRICAN MUSEUM:									
♀	94	111	20	60	22	22	4	4	4th
♀	91	?	19	63	22	23	3	3	4th

All the specimens are from Aus., Namaqualand.* The Hon. P. A. Methuen records the two Transvaal Museum specimens, referred by him to *A. atra*, as having been found at a height of 6500 ft. and 1450 ft. respectively. This is a rock or hill frequenting *Agama*, like *A. atra*. All the specimens captured by Capt. Knobel were found in rocky places, where they lived in the crevices of rocks.

3. AGAMA ATRA.

Agama atra, Daud. Hist. Rept. iv, p. 349 (1802) ; Dum. and Bibr. Erp. Gén. iv, p. 493 (1837) ; Bouleng. Cat. Liz. i, p. 352 (1885).

* Two of the specimens on the list, the first and last, belonging to the Kimberley Museum, are unfortunately no longer in existence; after having been sent to the senior author for study, they were lost at sea on their return to South Africa in September, 1918.

A. *Forma typica.*

Daudin's description is drawn up from two specimens stated to be in the Paris Museum.* The diagnosis is: "*Occipite spinosissimo, corpore suprà fusco squallido sub-atro, vittâ longitudinali flavescente suprà dorsum, abdomine gulâque cærulescentibus, caudâ sub-compressâ.*" The habitat was unknown, but Duméril and Bibron, who have fixed the definition of this species, say it is common at the Cape of Good Hope. I have therefore based the following description on specimens from the S.W. parts of South Africa, which may safely be regarded as representing *A. atra* in the sense given to it by Daudin and by Duméril and Bibron.

Form.—Head and body much depressed. Head as long as broad; snout short, rounded or obtusely pointed; canthus rostralis very short; nostril directed upwards and backwards, in a very convex, subtubular shield, pierced on the canthus rostralis; length of head $3\frac{2}{3}$ to 5 times in length to vent. Diameter of ear-opening equal to, or slightly less or slightly more than cleft of closed eye. Limbs strong, moderately elongate; the hind limb, pressed against the body, reaches the shoulder, the neck, or the ear; length of hand greater than depth of head; fingers short, third and fourth equal or fourth slightly the longer; tibia as long as the head or the foot, or a little shorter or longer; toes thick and short, third and fourth equal or fourth (very rarely third) slightly the longer, fifth extending as far as first or a little farther. Tail cylindrical in females, more or less compressed in males, longer ($1\frac{1}{10}$ to $1\frac{1}{2}$ times) than head and body.

Measurements:

	1.	2.	3.	4.
Snout to vent	82	116	93	101
Head	21	30	22	23
Width of head	21	30	22	23
Depth of head	11	16	12	14
Diameter of eye-cleft	3·5	4·5	4	4·5
„ „ ear-opening	3	4	3·5	4·5
Fore limb	43	52	44	51
Hand	16	18	15	18
Hind limb	60	80	61	74
Tibia	20	29	21	26
Foot	20	27	21	26
Tail	111	145	103	124

1. ♂, Simon's Bay. 2. ♂, Deelfontein. 3. ♀, Deelfontein. 4. ♀, Klipfontein.

Lepidosis.—Scales of upper parts very small (105 to 150 round middle of body) subequal or intermixed with few, irregularly scattered, enlarged or

* They do not seem to have been preserved, as they are not mentioned in A. Duméril's Catalogue of 1851, p. 101.

spinose scales ; mid-dorsal scales larger, feebly or more or less strongly keeled, passing generally into the much smaller laterals, which are strongly keeled and mucronate, with the keels pointing outwards instead of inwards ; groups of short spines on the neck and near the ear ; a very feeble marked nuchal crest, but no dorsal crest whatever. Upper head-scales not very unequal, smooth or obtusely keeled ; occipital feebly enlarged, exceptionally not at all ; 12 to 16 scales across the head from one superciliary series to the other; 12 to 16 upper labials on each side ; 2 to 4 series of scales between the upper labials and the nasal. Gular and ventral scales perfectly smooth, not mucronate. Scales on upper surface of tibia equal or subequal. Scale at the base of the claw, on the dorsal surface of the toes, uni- or tricarinate, and much longer than the others ; 16 to 22 scales under the third or fourth toe, in a longitudinal series ; the tips of the keels often dark brown or black. Caudal scales strongly keeled and mucronate, sometimes denticulated, the lower sometimes smooth or feebly keeled, in males often forming more or less distinct segments of 3 or 4 whorls ; a more or less developed vertebral crest in males, originating some distance from the base. Scales on upper surface of tibia equal.

Male with a single row of large preanal pores.

Coloration.—Olive-grey, brown, or reddish brown above, with blackish spots or dots, or with numerous small ocellar spots with yellowish centres ; sometimes a yellow or orange vertebral stripe, which may be interrupted ; cheeks blue in males ; throat and anterior part of belly dark blue in males, throat sometimes with a black network ; sides of belly sometimes vermilion red in males ; lower parts white in females, throat usually with bluish longitudinal lines or network.* In a few specimens from the Transvaal these throat lines were a bright pink and extended to the vent, forming a network on the abdomen.

In addition to the above-described strictly typical individuals, we now include under *Agama atra sensu stricto* individuals with still smaller scales (150 to 160 round middle of body), not intermixed with enlarged spinose scales, for which the name *A. micropholis* has been proposed by Matschie, Zool. Jahrb. Syst., v, 1890, p. 607, and *A. microterolepis* by Boulenger, Ann. and Mag. N.H. (6), xvii, 1896, p. 22. The types of both of these supposed species are from the Transvaal, but similar individuals occur near Kimberley along with others which show so complete a passage towards the true *A. atra* as to render the retention of *A. micropholis* even as a variety inadvisable.

Agama holubi, Bocage, Jorn. Sc. Lisb. (2), iv, 1896, p. 115, from the Modder River, of which *A. pulchella*, Bocage, *l.c.*, p. 116, appears to be a

* The coloration of some breeding males is very brilliant, the back showing varying shades of pink, the sides of the body reddish brown or purple, the lower parts a glowing ultramarine blue, the tail a rich lemon yellow.

synonym, is known to us from the description only. It is described as with 170 to 180 scales round the body, with irregularly scattered, strongly keeled and mucronate ones. We regard it provisionally as a variety of *A. atra*.

We propose to distinguish, as var. *rudis*, specimens with a coarser lepidosis, of which a definition is given further on.

Particulars of Specimens Examined.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
BRITISH MUSEUM:									
Simon's Bay ♂	82	111	21	60	20	20	3·5	3	3rd & 4th
,, ♀	84	?	18	55	19	20	3·5	3	3rd & 4th
Prince Albert ♀	93	102	22	65	23	23	4	4	4th
Deelfontein ♂	116	145	30	80	29	27	4·5	4	3rd
,, ♂	106	128	24	70	25	24	4	3·5	3rd & 4th
,, ♂	91	115	24	60	22	23	4	3·5	3rd & 4th
,, ♀	93	103	23	61	21	21	4	3·5	4th
,, ♀	82	91	20	54	19	19	3·5	3	4th
Klipfontein ♂	80	115	20	64	22	22	3·5	3	4th
,, ♀	101	124	23	74	26	26	4·5	4·5	4th
,, ♀	99	122	20	75	25	25	4·5	4	4th
Kimberley ♂	105	130	25	68	25	25	4·5	4	4th
,, ♂	105	?	24	67	24	25	4·5	4	4th
,, ♂	102	?	21	68	23	23	4·5	3·5	3rd & 4th
,, ♂	100	?	22	68	25	25	4·5	4	4th
,, ♀	90	115	21	62	21	22	4	3·5	4th
,, ♀	80	100	19	56	19	19	3·5	3·5	3rd & 4th
Johannesburg ♂	103	?	26	70	25	25	4	3·5	3rd
,, ♂	103	?	24	68	23	23	4	4	4th
,, ♀	82	91	19	53	18	18	3·5	3	3rd
Heidelberg, Transvaal ♂	108	?	24	71	24	25	4·5	4·5	3rd & 4th
Rustenburg ,, ♂ (Types of *A. microterolepis*.)	115	160	25	76	26	26	5	5	4th
,, ,, ♀ (Types of *A. microterolepis*.)	100	?	22	65	22	22	4	4	4th
,, ,, ♀ (Types of *A. microterolepis*.)	96	125	21	68	24	24	4	3·5	4th
Naroep, Namaqualand ♂	125	?	28	84	32	28	5	5	4th
,, ♀	94	120	21	68	23	23	4	4	4th
,, ♀	85	112	21	66	22	23	4	4	4th
KIMBERLEY MUSEUM:									
Kalk Bay ♂	84	116	20	62	21	23	4	4	4th
Table Mountain ♂	81	?	18	50	20	20	3	3	4th
Gordon's Bay ♂	76	106	18	51	18	18	3	3	3rd & 4th
,, ♂	68	98	17	50	18	19	3	3	3rd & 4th
,, ♀	65	86	15	42	15	15	3	2·5	3rd & 4th
Paarl ♂	69	102	16	48	18	19	3	3	3rd & 4th
Victoria West ♀	85	?	19	51	18	19	3·5	3	4th slightly
Hanover ♂	90	?	21	63	22	22	4	3·5	4th

	1.	2.	3.	4.	5.	6.	7.	8.	9.
De Aar ♂	94	?	21	61	22	21	4	4	4th
„ ♂	109	?	24	64	24	21	4	4	3rd & 4th
„ ♀	90	92	19	54	20	18	4	4	4th
„ ♀	92	?	19	55	20	17	4	4	3rd & 4th
Hopetown ♀	101	?	21	61	21	22	3·5	3·5	4th
Fort Richmond ♂	108	?	23	67	24	23	4	4	4th
Enslin ♂	93	137	20	58	24	24	3·5	4	4th
„ ♂	104	152	23	66	26	23	4	4	3rd & 4th
„ ♀	98	120	21	57	22	21	4	3	3rd & 4th
„ ♀	88	110	18	55	21	20	4	4	4th
Kimberley ♂	105	143	24	70	23	23	?	4	4th
„ ♀	92	116	20	59	19	21	3·5	3·5	3rd & 4th
„ ♀	76	101	18	49	18	17	3	3	3rd & 4th
„ ♀	82	?	20	51	19	19	3	3	4th
„ ♀	79	104	18	52	18	19	3	3·5	4th
„ ♀	97	105	21	59	20	21	4	4	4th
„ ♂	120	?	25	68	24	24	4	4	4th
„ ♀	93	109	19	61	22	20	3	3	3rd & 4th
„ ♂	100	137	21	60	22	20	3·5	4	4th
„ ♂	100	136	20	63	23	22	4	4	4th
„ ♂	101	124	21	65	23	24	4	4	4th
„ ♂	107	?	23	64	24	22	4	4	3rd & 4th
„ ♂	100	130	22	64	23	22	5	4	4th
„ ♂	96	?	20	62	22	23	4	4	4th
„ ♂	100	143	22	64	25	23	4	4	4th
„ ♂	99	?	22	62	23	21	4	3	4th
„ ♀	79	109	18	57	20	20	3	3	4th
„ ♂	97	132	21	63	22	21	4	4	4th
„ ♂	105	?	23	66	24	22	4·5	4	4th
„ ♂	85	119	19	54	19	22	3	4	4th
„ ♀	77	95	17	52	18	19	3	3	4th
„ ♂	98	?	21	63	22	22	5	4	4th
„ ♀	91	107	19	55	20	18	3	4	4th
„ ♂	100	136	24	65	24	24	4	4	4th
Thabanchu ♀	77	90	18	50	17	17	4	3	4th
„ ♂	93	?	22	55	21	20	4	4	3rd & 4th
„ ♂	85	108	21	56	19	20	3	3	3rd & 4th
„ ♀	79	93	19	50	16	17	3	3	3rd & 4th
„ ♂	84	100	20	55	20	19	4	4	3rd & 4th
„ ♂	104	?	21	61	22	22	4	4	3rd & 4th
„ ♂	99	?	21	57	22	21	4	4·5	3rd & 4th
„ ♂	94	115	20	59	22	21	3·5	4	4th
„ ♂	90	?	20	61	22	22	4	3·5	4th
„ ♀	86	?	20	47	16	16	4	3	3rd & 4th
„ ♀	85	?	18	52	17	18	3	3	3rd & 4th
„ ♂	105	126	23	65	23	21	4	4	4th slightly
Bloemfontein ♂	110	?	25	63	22	22	4	3·5	4th
„ ♂	104	142	23	62	22	23	4	4	3rd & 4th
Immegrant, O.F.S. ♂	94	?	21	63	21	22	4	4	4th

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Immegrant, O.F.S. ♀	81	100	18	50	18	18	3	3	3rd & 4th
Barkly West ♀	86	96	20	50	18	18	3·5	3	3rd & 4th
" ♀	94	?	20	54	20	19	3	3·5	4th
" ♂	101	?	22	64	23	22	4	4	3rd & 4th
" ♂	95	123	20	63	22	22	4	4·5	4th
Riverton ♂	107	?	22	64	23	22	4	4	3rd & 4th
" ♀	94	?	21	55	21	20	4	3·5	4th
" ♂	105	?	22	65	24	23	4	4	4th
" ♂	108	?	23	62	23	22	4	4	4th
" ♂	106	?	23	65	23	25	3	3	4th
" ♀	90	?	18	52	19	18	3	3	4th
" ♂	88	?	19	61	22	20	3·5	3	4th
" ♂	112	?	23	68	23	23	4	3·5	3rd & 4th
" ♀	95	107	21	55	19	20	3	3	3rd & 4th
" ♂	88	119	21	60	21	22	?	3	3rd & 4th
Rooidam, Kimberley ♀	80	110	16	57	19	20	3·5	4	3rd & 4th
" ♀	76	100	18	53	18	19	3	3	3rd & 4th
" ♂	91	?	20	63	21	22	3·5	4	3rd & 4th
Taungs ♂	97	126	21	56	22	20	4	4	4th
" ♀	91	?	19	56	20	19	3·5	4	4th
" ♀	78	?	17	48	18	17	3	3	4th
Watersmeet ♀	88	93	19	52	19	16	4	4	4th
" ♂	107	?	23	64	24	21	4·5	4	4th
" ♂	90	116	20	60	21	21	3	4	3rd & 4th
" ♀	82	94	19	53	18	18	3·5	3	3rd
Otto's Hoop ♂	104	?	26	72	24	25	4	4	4th slightly
Steyensburg ♂	104	125	23	62	23	21	4·5	4	4th
ALBANY MUSEUM:									
Graaf Reinet ♂	82	?	20	53	20	21	4	4	4th
Williston ♂	122	168	25	75	28	25	4·5	4·5	4th
" ♂	96	133	22	60	23	23	4	4	4th
Victoria West ♂	102	?	24	66	24	23	4	3·5	4th
" ♀	80	91	18	54	20	18	3	3	4th
" ♂	81	?	18	51	19	19	3	3	4th
" ♀	89	?	20	58	22	20	3·5	3·5	4th
Ludlow ♂	100	?	23	61	23	20	4	4	3rd & 4th
Utlolas ♂	90	113	21	58	22	20	3	3	4th
Steinkopf ♀	85	?	20	59	22	21	3	3	4th
Kimberley ♀	79	?	18	52	20	18	3	2·5	4th
" ♀	80	92	19	49	18	17	3	3	3rd & 4th
" ♀	88	103	19	56	20	19	3	3	3rd & 4th
" ♂	98	?	23	63	22	21	3·5	3·5	4th
" ♀	78	97	18	53	19	18	3·5	3·5	3rd & 4th
" ♀	85	109	19	54	19	18	3	3	3rd & 4th
" ♂	107	?	23	67	24	23	4	4	4th
" ♂	103	131	23	62	23	22	3·5	3·5	4th
" ♂	89	125	20	63	22	23	4	4	4th
" ♂	105	?	22	68	25	22	4	4	4th

	1.	2.	3.	4.	5.	6.	7.	8.	9.
TRANSVAAL MUSEUM:									
Knysna ♀	78	85	17	49	16	18	3	3	3rd & 4th
Victoria West ♀	80	99	19	56	19	20	3·5	3·5	4th
Hanover ♀	104	?	23	66	24	22	4	4	3rd & 4th
„ ♂	105	128	22	65	24	23	4	4	4th
Kimberley ♂	101	133	23	63	22	21	4	3·5	4th
„ ♂	97	?	22	63	22	22	4	4	4th
„ ♂	103	?	23	64	25	21	4	4	3rd & 4th
„ ♂	90	110	19	58	21	20	3·5	3	4th
„ ♂	108	?	22	59	21	20	4	3·5	4th
Kraikluft ♀	82	91	18	54	19	19	3	3	3rd
Narüdas Süd ♀	80	98	18	52	19	20	3	3	4th
Schweizer Reneke ♂	100	?	21	60	22	21	4	4	3rd & 4th
„ ♂	100	?	20	59	22	21	4	4	3rd & 4th
„ ♂	89	?	20	60	21	21	3·5	4	4th
Venterskroom ♂	92	125	19	60	22	21	3	4	4th
„ ♂	93	116	20	61	22	22	3·5	4	4th
Fredrickstad ♀	80	90	17	53	19	19	3	3	4th
Orange Grove ♂	110	?	23	69	25	24	4	4	3rd & 4th
„ ♀	96	107	19	59	21	21	3·5	3·5	4th
Woodbush ♂	98	136	23	68	24	24	4	4	4th
„ ♂	91	120	22	65	22	22	3·5	4	4th
Rosslyn ♂	123	?	25	77	29	25	5	5	3rd & 4th
„ ♂	122	159	23	77	28	25	5	5	3rd
„ ♂	126	?	26	?	30	?	5	5	?
„ ♂	121	146	23	75	28	25	4	5	4th
„ ♀	99	114	21	61	23	20	4	4	4th
„ ♀	93	106	19	61	22	22	4	4	4th
„ ♀	80	100	18	56	20	20	3	4	4th
„ ♀	96	?	20	59	22	21	4	4	4th
De Kroon ♂	123	?	27	78	30	26	5	5	4th
„ ♀	105	?	21	65	23	20	4	4	4th
„ ♂	115	?	24	74	28	25	4	4·5	3rd & 4th
„ ♂	104	?	22	62	23	22	4	5	3rd & 4th
Bleskop ♂	109	152	23	72	26	24	4	4·5	3rd & 4th
„ ♂	106	149	22	71	26	25	4	4·5	4th
„ ♂	96	125	20	67	24	23	3·5	3·5	4th
„ ♂	105	124	22	70	25	24	3.5	4	4th
„ ♂	114	154	24	75	27	26	4	5	4th
„ ♀	84	102	18	57	20	19	3	4	4th
„ ♂	105	144	22	68	26	25	4	5	4th
„ ♂	110	?	24	76	28	25	4	5	4th
„ ♂	108	?	22	75	27	26	4	5	4th
„ ♀	82	102	19	59	21	20	3	4	4th
„ ♀	78	103	17	55	20	20	3	4	4th
„ ♀	86	109	18	59	21	21	3	4	4th
„ ♂	101	122	21	67	24	23	4	5	4th
De Deur Evaton, Kolkenbek ♀	78	?	17	52	19	17	3·5	3	4th slightly
Zwartkopjes ♀	86	?	19	60	21·5	20	4	4	4th

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Zwartkopjes ♂	112	?	24	74	27	27	4	5	3rd & 4th
Sjambokstad ♀	91	114	20	63	22	22	4	4	4th
,, ♂	117	?	24	76	28	26	4	4	3rd & 4th
Bonaccord Quarry ♂	112	?	21	74	27	24	4	4	4th
,, ♂	103	?	22	63	25	24	4	4·5	4th
,, ♀	90	96	19	59	21	20	3	3	3rd
SOUTH AFRICAN MUSEUM:									
Cape Division ♂	92	123	20	66	23	24	4	4	4th
Uitenhage ♂	108	?	24	66	25	22	4	5	4th slightly
Tulbagh ♂	105	134	23	70	26	25	3·5	4	4th slightly
Touw's River ♂	89	127	21	61	21	23	4	4	4th
Matjesfontein ♂	104	130	24	69	25	24	4	4	3rd
,, ♀	91	101	21	58	20	20	4	3·5	4th slightly
Prince Albert Division ♂	115	?	21	65	24	23	4	5	4th
,, ♂	91	124	22	65	23	23	4	3·5	4th
East London ♀	90	128	22	60	20	22	3·5	3	4th slightly
Nieuwoudtville ♂	94	134	20	70	25	25	4	4	4th slightly
Hanover District ♂	93	?	22	66	24	23	4	4	3rd slightly
Burghersdorp ♂	98	117	24	64	22	22	4	4	4th slightly
Smithfield ♂	85	109	20	59	19	22	4	4	4th
Springbok ♀	82	?	18	61	21	22	3	3	4th
Ookiep ♂	112	?	23	83	29	29	4	4	4th slightly
,, ♂	122	?	28	83	31	29	4	5	4th slightly
,, ♂	115	?	23	83	29	30	4	5	4th slightly
,, ♂	85	?	19	56	20	20	4	3·5	4th
,, ♂	121	166	23	80	28	28	4	4	3rd & 4th
,, ♂	136	?	29	93	34	32	5	6	4th slightly
,, ♂	98	126	19	68	24	24	3·5	4	4th
,, ♀	91	?	20	63	22	24	3	4	4th
,, ♂	121	160	24	80	30	28	4	5	4th
,, ♂	101	134	22	74	26	28	4	5	4th
,, ♂	124	152	26	32	29	28	4	5	4th
,, ♂	92	105	20	60	22	21	4	4	3rd slightly
,, ♂	129	?	28	87	32	29	4	5	3rd & 4th
,, ♂	130	?	28	84	31	28	4	5	4th
,, ♂	128	?	28	84	31	28	4	5	4th
,, ♂	110	153	23	78	27	28	4	5	4th
,, ♂	106	149	23	74	26	27	3·5	5	4th slightly
,, ♂	85	119	20	58	21	20	4	4	3rd & 4th
,, ♀	100	118	20	65	22	22	4	4	4th
,, ♂	94	123	23	59	22	20	4	4	3rd & 4th
,, ♂	115	155	23	80	28	29	4	4	4th
,, ♂	118	?	25	78	29	27	4	4	4th
,, ♂	95	?	23	70	24	26	3·5	4	4th slightly
,, ♀	110	139	23	73	26	24	4	5	4th
,, ♂	117	?	26	76	27	26	?	5	4th
Naroep ♀	97	132	22	68	25	23	4	4	3rd & 4th
Concordia ♂	116	?	24	74	27	26	4	5	4th
Port Nolloth ♂	115	146	26	78	28	28	4	5	4th

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Port Nolloth ♂	117	164	27	82	29	29	4	5	4th
Oograbies ♀	100	116	21	71	25	23	4	4	4th slightly
Springbok and Steinkopf ♂ .	115	147	27	78	28	26	4	5	4th slightly
Steinkopf and Rymond's Drift ♀	92	110	22	60	21	20	4	4	4th
" " ♂	112	?	24	76	27	26	4	4	4th
" " ♂	117	161	25	74	26	25	4	4	4th
" " ♀	98	119	22	66	23	21	3	4	3rd slightly
" " ♂	105	?	22	80	28	27	4	5	3rd & 4th
Kuboos ♂	119	?	27	78	28	28	4	5	3rd & 4th
Kimberley ♀	92	116	20	59	22	20	3·5	3	4th
" ♂	104	?	22	67	23	23	4	4·5	4th
" ♀	77	91	17	48	17	17	3	3	4th
Krugersdorp ♂	95	?	23	64	22	23	4	4	4th
Middelburg District, C.G.H. ♂	100	?	23	64	23	21	3·5	3·5	4th

The following discrepancies between several specimens and the foregoing description were noted:

Toes rather long and slender: Table Mt. ♂, Paarl ♂, Kimberley 4 ♂, Rooidam ♂, 2 ♀, Riverton ♂, Watersmeet ♀, Narüdas Süd ♂, Bon Accord Quarry ♂, ♀.

Tail rounded: Kimberley ♂, Riverston ♂.

Little groups of spinose scales scattered here and there dorsally: Paarl ♂, Kimberley ♂, Bloemfontein ♂, Otto's Hoop ♂.

Preanal pores in two rows: Kimberley, Barkley West, Riverton, Williston, Rosslyn, Bleskop, Ookiep.

Occipital scale entirely absent: Kimberley ♂.

Adpressed hind limb reaching beyond the ear: Rooidam 2 ♀, ♂.

Head longer than broad: Knysna ♀, Narüdas Süd.

The following combinations of characters are noted:

Paarl ♂. Toes long and slender; groups of enlarged spinose scales scattered over the back.

Kimberley ♀. Toes long and slender; numerous little clusters of slightly enlarged spinose scales scattered over the back.

Kimberley ♂. Toes slender; tail rounded; no nuchal crest. Preanal pores very large. A few other males from Kimberley have unusually large preanal spores.

Kimberley ♂. Toes very short and thick on the right foot, slender on the left.

Schweizer Reneke ♂. Dorsal scaling very small, but strongly keeled, and extending for a short distance on to the tail, then suddenly meeting enlarged spinose ones; tail unusually compressed and crested.

Rosslyn ♂. Dorsal scales very small on middle of back, not keeled (132 scales round middle of body); no nuchal or dorsal crest whatever; toes short and thick, fifth extending far beyond the first.

De Kroom ♂. Scales on middle of back not imbricate, only very slightly keeled (136 scales round middle of body); no nuchal or dorsal crest.

Tulbagh ♂. Dorsal scales not imbricate, hexagonal and strongly keeled; strong nuchal and dorsal crest for some distance below the shoulders, continued along the remainder of the back by strong keels on the enlarged mid-dorsal scales; a distinct gular pouch; tail very compressed and crested.

Nieuwoudtville ♂. Dorsal scales small, strongly keeled and mucronate; double row of slightly enlarged spinose scales forming a low but distinct dorsal crest.

Ookiep ♂. Dorsal scales small, strongly keeled, rounded; becoming abruptly very much enlarged on the tail.

Ookiep ♂. Dorsal scales small, equal, those on the vertebral line smooth, the others strongly keeled and mucronate; scales on upper arm and tibia larger than the dorsals; head long and pointed.

Ookiep ♀. Dorsal scaling of this specimen somewhat approaches that of *A. planiceps*. Another ♀ and a ♂ from this locality have the general appearance of *A. planiceps*.

Ookiep ♂. Dorsal scales very small; snout pointed; mid-dorsal scales smooth, otherwise keeled; small dorsals becoming abruptly enlarged on the tail.

Concordia ♂. Scaling throughout very small; head long and pointed.

Steinkopf—Rymond's Drift ♀. Scales on and at either side of the mid-dorsal line much larger than those at the sides; all dorsal scales more or less strongly keeled but not mucronate.

In a great many cases the dorsal scales are strongly keeled but rounded at the apex, not mucronate. In other cases they are rounded or hexagonal at the base, not imbricate. Sometimes smooth except low down on the sides.

The typical *Agama atra* is distributed in the west from Damaraland to the Cape, and it is also found in the interior of Cape Colony, the Orange Free State and the Transvaal.

In the Kimberley neighbourhood this lizard is confined to the kopjes, where it makes its home in the clefts of the rocks, coming out to get food and bask in the sun. During the winter months it hibernates in these clefts, and at such times is found in company with *Zonurus polyzonus* and *Pachydactylus bibroni*.

Specimens with uniform dorsal scales might be confounded with *Agama kirkii*, Blgr., found in Southern Rhodesia, in which, however, the lateral scales are directed inwards, as in *A. hispida* and *A. anchietae*, and a vertebral serration or well-developed crest extends along the whole body; the occipital is usually more enlarged.

B. Var. RUDIS, var. nov.

Specimens from the coastal districts of South Africa, east of the Cape Peninsula and as far north as Delagoa Bay, have a coarser lepidosis, with

numerous strongly enlarged spinose scales on the back; 90 to 110 scales round middle of body; nasal shield less swollen than in the typical form. 15 to 19 scales in a longitudinal series under the third or fourth toe. Scales on upper surface of limbs sometimes very unequal in size:

Measurements, in millimetres:

	♂	♀
From snout to vent	90	85
Head	23	21
Width of head	23	21
Depth of head	14	13
Diameter of eye-cleft	4	4
,, ,, ear-opening	4	3·5
Fore limb	44	40
Hand	18	16
Hind limb	63	58
Tibia	22	20
Foot	22	20
Tail	115	102

This is the common and only form at Mossel Bay, East London, and Port Elizabeth, and when series are compared with the true *Agama atra* from near Cape Town and the interior of the Cape Province the difference is very striking. Curiously, the same variety appears to exist in the Transvaal * and in the neighbouring part of Matabeleland.†

Particulars of Specimens Examined.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
British Museum:									
Port Elizabeth ♂	71	92	17	52	18	18	3	3	3rd & 4th
,, ♂	62	82	16	46	15	16	2·5	2·5	3rd & 4th
,, ♀	85	102	21	58	20	20	4	3·5	4th
Cape Recife ♂	86	117	21	58	20	21	4	3·5	4th
Delagoa Bay ♂	57	72	15	42	14	15	2·5	2·5	4th
Matabeleland ♂	90	115	23	63	22	22	4	4	4th
Kimberley Museum:									
Mossel Bay ♂	75	117	20	60	21	22	3·5	4	4th slightly
,, ♂	76	96	18	57	19	22	3·5	3	4th
,, ♀	86	110	20	55	20	22	3·5	3	4th
,, ♂	79	?	19	59	20	22	3·5	3	4th
,, ♂	85	113	20	60	22	21	3·5	3·5	3rd
,, ♀	77	117	18	54	19	20	3	3	4th slightly

* Female noticed and figured by Gough, Ann. Trans. Mus., i, 1909, p. 193, pl. xxiv, fig. 1.

† A single specimen forms part of a small collection from Matabeleland, between the Shasha and Macloostie Rivers, presented to the British Museum by Mr. Claude Beddington in 1892.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Mossel Bay ♀	84	?	20	51	19	19	3·5	3·5	3rd & 4th
„ ♂	94	?	24	63	21	23	4	4	4th
„ ♀	88	101	21	60	22	21	4·5	3	4th
„ ♂	76	100	?	56	21	21	3·5	3·5	4th
„ ♂	94	?	24	69	25	24	4	4	4th
Oudtshoorn ♂	105	145	26	75	27	27	4	4	4th
„ ♂	111	?	26	75	29	26	4·5	5	4th
East London ♀	88	121	19	56	20	21	3	3	4th
„ ♀	68	99	16	50	18	19	3	2	4th
„ ♂	71	106	16	49	18	21	3	3	3rd & 4th
Albany Museum:									
Grahamstown ♂	82	104	18	54	19	19	4	3	4th
„ ♀	78	96	18	45	18	18	3	3	4th
„ ♂	76	107	20	55	20	20	?	3	4th
Slaai Kraal ♀	72	88	18	50	18	18	3·5	2·5	4th
Keilands ♀	77	94	18	50	19	18	3·5	3·5	4th
Cradock ♂	81	110	19	55	19	19	3·5	3·5	4th
Shawbury ♂	81	98	19	55	19	19	4	3	4th
South African Museum:									
Port Elizabeth ♂	87	116	22	59	20	21	4	3	4th
Touw's River ♀	99	123	22	64	23	23	4	4	4th
Commandofontein ♀	99	119	23	61	21	21	4	3	4th slightly
Burghersdorp ♀	83	?	19	51	18	18	4	3·5	4th slightly
Transvaal Museum:									
East London ♀	93	?	20	53	21	21	3	3	4th
Grahamstown ♂	96	121	23	64	23	23	4	3	4th

The following are notes on individuals which we propose to place in this variety:

Mossel Bay 2 ♂, ♀. Head only slightly depressed; enlarged spinose scales arranged in more or less zig-zag longitudinal series; adpressed hind limb reaching the eye. All the Mossel Bay specimens with more or less slender feet.

Mossel Bay ♀. Dorsal scaling mucronate throughout, and very strongly keeled; head depressed; scaling on tail uniform.

Mossel Bay ♂. Head not at all depressed, exactly as in the *A. hispida* group. A very strong nuchal crest and a slight dorsal crest for some distance below the shoulders; tail compressed laterally some distance from the vent.

East London 2 ♀, ♂. Numerous enlarged strongly keeled and mucronate scales scattered irregularly over the back; toes very slender; caudal scales in whorls.

East London ♀. Dorsal scaling not quite so coarse as in the specimens from Mossel Bay.

Commandofontein ♀. Enlarged dorsals arranged more or less in transverse rows.

Touw's River ♀. Dorsal scaling not so coarse as in specimens from Mossel Bay.

Conclusion.

South Africa presents many zoogeographical problems, but none is so intricate as that of the distribution of the genus *Agama*.

As regards *A. hispida*, it seems that a line drawn along the twenty-sixth meridian indicates, roughly, the limit between the ranges of the vars. *armata* (eastern) and *aculeata* (western); nowhere do these two forms overlap. At the extreme east, from the Zambesi to Natal, var. *armata* exists alone, but towards the west, from Rhodesia to the north-eastern corner of the Cape Colony, it is accompanied or replaced by var. *distanti*, which is the prevailing form in the Transvaal and the Orange Free State. In the west, from 25° lat., var. *aculeata* is accompanied by var. *brachyura*, which, from 30° lat., passes gradually into the typical *hispida* in the south —the only form occurring at the Cape.

A. anchietae and its varieties *methueni* and *knobeli* are N.W. forms.

A. atra is a more southern species, not recorded within the tropics; at the extreme S.E. of the Cape it is accompanied by var. *rudis*, which south and east of the great mountain ranges replaces the typical form, extending as far to the north as Delagoa Bay.

It was at first thought that it might be possible to co-relate the distribution of the several varieties with the various botanical regions as set forth by Dr. I. B. Pole-Evans in the Official Year Book for 1917, but when a map had been constructed for the Agamas it was found that some of the varieties, *e. g. A. aculeata*, had such a wide distribution that co-relation was impossible.

In some cases, however, distribution is restricted to comparatively small areas, and it may be possible that a systematic survey will show that these forms are confined to certain localized botanical areas. In the absence of a detailed survey it is not easy to say, and this side of the subject needs thorough investigation by reliable collectors on the spot.

Thus in regions of sandy waste there may be little oases of grass and of thorn trees, with var. *brachyura* inhabiting the former and var. *aculeata* in possession of the latter.

We have, for example, recorded var. *brachyura* from Aus and from Worcester. This at first sight seems to preclude the possibility of a regional distribution, but on reference to the above-mentioned map of the botanical regions it will be found that there is a fair-sized patch of country, just south of Worcester, indicated as being the same as the country round Aus.

We have recorded varieties *aculeata*, *distanti*, *brachyura* and *hispida* from Little Namaqualand.

Dr. L. Péringuey describes this district as follows: "From Port Nolloth

to a distance of 12 miles there is nothing but sand hills or sand hummocks *ad infinitum*, and during the dry season they become carpeted with flowers after the first winter rains. Ograbies, 15 miles north from Port Nolloth, is partly rocky, partly sandy. From Ograbies the sand ceases, and is replaced to Anenous railway station (50 miles from Port Nolloth), where the heavy ascent of the mountain begins, by rocky, grassy or bushy ground."

From this it is clear that what is wanted is intensive study in a neighbourhood where two or more forms are known to occur. The records are not always as trustworthy as could be wished owing to the insufficient localisation of their captures by collectors.

In the opinion of the junior author it is not at all clear that environment has been an important factor in the distribution of these several forms of the genus *Agama*, or that it is this adaptation which has led to evolution on so many minor lines.

If natural selection were the process whereby the original homogeneous (this is an assumption) stock branched out into the various forms which segregate in areas of more or less different environmental conditions, it follows, of course, that the differences between varieties *aculeata*, *distanti*, etc., are adaptative. So far as can be seen, however, there is no evidence that the difference between var. *distanti* and var. *aculeata* (for example) has anything to do with, or at any rate is the direct result of, a difference in environmental conditions, taking these to include food, enemies, etc., as well as the nature of the surroundings. The fact that specimens from the Waterberg division of the Transvaal, well within the area of var. *distanti*, show such a wide range of variation in the direction of other allied forms, would seem to prove that natural selection has not operated strongly in regard to these characters.

In order to conceive the drift of evolution in these lizards, it is necessary to picture to ourselves a hypothetical ancestral form of *Agama*, and basing our views on considerations derived from a general survey of the family *Agamidae*, the following characters may be postulated for this ideal prototype:

(1) Body moderately elongate, neither compressed nor depressed, covered with scales of equal size.

(2) Head not broader than long, not or but moderately depressed, covered with subequal, non-tuberculous scales.

(3) Ear-opening large.

(4) Nostril lateral, not tubular.

(5) Limbs moderately elongate, covered with equal scales.

(6) Toes rather elongate, subcylindrical, very unequal in length, fourth the longest, fifth much longer than the first.

(7) Tail cylindrical, much longer than head and body, covered with equal scales not forming whorls.

The tropical African form nearest to this prototype is clearly *A. mossambica* (N. Rhodesia, Nyassaland, Portuguese East Africa), which is represented to the West (Angola, Damaraland) by the more depressed *A. planiceps*, and the most extremely remote from it the typical *A. hispida* from the Cape, the other forms of the latter species filling up the gap, more or less, from north to south.

Now this is exactly what one should have expected on the assumption, founded on the absence of the *Agamidae* from Madagascar, which seems to show that, like the *Lacertidae*, *Agama* did not extend its range south of the Equator until after a connection between the continent and the great island had ceased to exist.* If, as we believe, the forms of *Agama* now spread over South Africa are, geologically speaking, of recent origin, it is quite legitimate to suppose that they represent the actual steps through which the genus has passed in its evolution and gradual dispersal.

The directions of the lines of evolution are not only traceable in *A. hispida* in the broad sense, but also in *A. atra*, the most extreme form of which, in accordance with these principles, is the var. *rudis* of the extreme south, but having probably thence migrated again northwards along the coastal region. It seems, if we consider *A. knobeli* as the initial form of the *A. atra* group, that this group has spread from the north-west to the south-east, while *A. hispida* has followed two parallel lines – an eastern (var. *armata*) and a western (var. *aculeata*).

* *Cf.* Boulenger, C.R. Ac. Sci., Paris, 1918, p. 594.

[**Note.**—A Map showing the distribution of the genus *Agama* has been omitted and will appear in a subsequent Part of the Transactions.]

A POSSIBLE LUNAR INFLUENCE UPON THE VELOCITY OF THE WIND AT KIMBERLEY.

(FOURTH PAPER.)

BY J. R. SUTTON.

(With one Text-figure.)

The argument upon which the previous papers have been based is the almost axiomatic one that since the moon can raise an appreciable tide in the atmosphere it must also be able to create an appreciable wind. For there cannot be an air tide without an air movement. The wonder is that the question has not been tested before for various places lying between the temperate zones. But the expectation with which the inquiry was started, namely, that the air movement would be a direct function of the air tide, and hence show a simple small semi-diurnal oscillation of speed, has not been exactly verified. A variation of velocity depending on the hours of the lunar day has been found, but surprisingly large and of a special type, which would appear to be little more directly related to the air tide than the normal diurnal winds are to the normal diurnal pressures. The object of that portion of the inquiry with which this paper deals is to determine whether there are any points of agreement between the air tides and the lunar wind period sufficiently definite to form the nucleus of a theory which could be used to explain the comparatively great air speeds attributable to the moon's influence.

For this purpose the air-tidal variation at perigee and at apogee has been determined for ten years of observation, 1897 to 1906, as shown in Table I, using the hourly pressure deviations* from the monthly means for the day of perigee and of apogee, together with those for the day before and the day after. The period is shorter than that used for the wind, but since the air tides are fairly regular it is probably sufficiently long for the immediate purpose; and in any case the arithmetic involved is as much as my wife and I can undertake for the present. In order to avoid the use of minus signs the tabular quantities have all been augmented by one inch: thus, *e. g.* 1·0023 means + ·0023, and ·9950 means − ·0050.

* By Sabine's method, Phil. Trans., 1847.

In Table 1, column 1 shows the hour of the lunar day.

Column 2 the pressure variations at perigee when the moon's upper meridian passage (= U.M.P.) occurs within two hours of noon.

Column 3 the same for near midnight.

Column 4 the same when U.M.P. falls between II and X, and between XIV and XX ("Horizon").

Column 5 the mean of columns 2, 3, 4.

Column 6 the pressure variations at apogee.

Column 7 the mean of columns 5 and 6.

Column 8 is added to show the velocity deviations for perigee and apogee together. The quantities are taken from the second and third papers.

TABLE I.—*Mean Hourly Air-Tidal Variation.*

Hour.	Perigee P.				Apogee A.	$\frac{P+A}{2}$	Wind. $\frac{P+A}{2}$
	Noon.	Midnight.	Horizon.	Mean.	Mean.		
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Mile.
L M.P.	·9958	1·0055	1·0107	1·0043	·9952	·9997	10·039
II	·9966	1·0057	1·0106	1·0045	·9947	·9996	10·070
III	·9961	1·0052	1·0096	1·0038	·9936	·9987	10·058
IV	·9955	1·0043	1·0092	1·0032	·9932	·9980	10·001
V	·9950	1·0033	1·0078	1·0022	·9924	·9973	9·932
VI	·9953	1·0042	1·0075	1·0026	·9924	·9975	9·884
VII	·9957	1·0039	1·0083	1·0029	·9922	·9976	9·894
VIII	·9953	1·0037	1·0082	1·0026	·9918	·9972	9·927
IX	·9982	1·0040	1·0075	1·0034	·9921	·9977	9·949
X	·9987	1·0046	1·0075	1·0037	·9935	·9986	9·939
XI	·9998	1·0061	1·0078	1·0048	·9939	·9994	9·924
XII	1·0013	1·0052	1·0078	1·0049	·9946	·9997	9·910
U.M.P.	1·0023	1·0042	1·0066	1·0044	·9953	·9999	9·904
XIV	1·0 22	1·0036	1·0063	1·0041	·9954	·9997	9·920
XV	1·0017	1·0027	1·0041	1·0028	·9943	·9985	9·933
XVI	1·0015	1·0017	1·0030	1·0020	·9936	·9978	9·940
XVII	1·0008	1·0011	1·0022	1·0013	·9933	·9973	9·932
XVIII	·9994	1·0000	1·0028	1·0007	·9934	·9970	9·914
XIX	·9988	1·0002	1·0017	1·0003	·9935	·9969	9·908
XX	1·0018	·9995	1·0013	1·0008	·9936	·9972	9·904
XXI	1·0015	·9998	1·0008	1·0006	·9943	·9975	9·917
XXII	1·0019	1·0005	1·0001	1·0008	·9944	·9976	9·932
XXIII	1·0050	1·0018	·9995	1·0020	·9954	·9987	9·954
XXIV	1·0054	1·0011	·9988	1·0016	·9958	·9987	9·968
L.M.P.	1·0070	1·0013	·9975	1·0018	·9960	·9989	10·007
Average.	·9997	1·0029	1·0051	1·0026	·9939	·9983	9·946
No. of days	121	143	131	395	399	794	1758

Air Tide Features.

There is a remarkable difference between the runs of the numbers in the different columns:

(A) The seventh column (perigee and apogee together) shows principal maxima at lunar noon and near lunar midnight, a secondary maximum at moonrise replacing the moonrise minimum, and a definite minimum near moonset. There is, moreover, on the whole a definite fall of pressure from beginning to end of the lunar day. The range is ·003 inch.

(B) The mean perigee curve has its principal maxima before noon and after midnight, a secondary maximum at moonrise, and a curious asperity at XXIII. The general fall of pressure during the lunar day is pronounced. The range is nearly ·005 inch.

(C) On the other hand, the apogee curve shows on the whole a small general rise, with maxima a little after lunar noon and perhaps before lunar midnight. It has the asperity at XXIII, and some tendency to a secondary maximum at moonrise, neither very definite. The range is about ·004 inch.

(D) The noon perigee curve shows a large general rise during the lunar day, with principal maxima after noon and after midnight. The secondary maximum at moonrise is plainly visible, and there are also signs of the asperity at XXIII. The range between moonrise and U.M.P. is about ·007 inch, that from moonset to L.M.P. about ·008 inch.

(E) The midnight perigee curve shows a general fall during the lunar day, with maxima before noon and after midnight. The moonrise maximum is large and falls a little early. The asperity at XXIII is also large. The range is perhaps ·003 inch.

(F) Almost the only prominent characteristic of the horizon perigee curve is the large general fall during the course of the lunar day. The maximum at moonrise is as large as it is on the noon and midnight curves, but the U.M.P. and L.M.P. maxima and the moonset minimum are almost evanescent, and the tidal effect consequently almost lost.

(G) The small asperities—namely, that at XX on the noon perigee curve, at XIX on the midnight perigee one, and at XVIII on the horizon perigee one—are possibly accidental, and only the first of the three is reflected in the mean perigee curve. There is, however, an analogue at XXI on the mean apogee curve. These asperities may have some resemblance to the moonrise maximum.

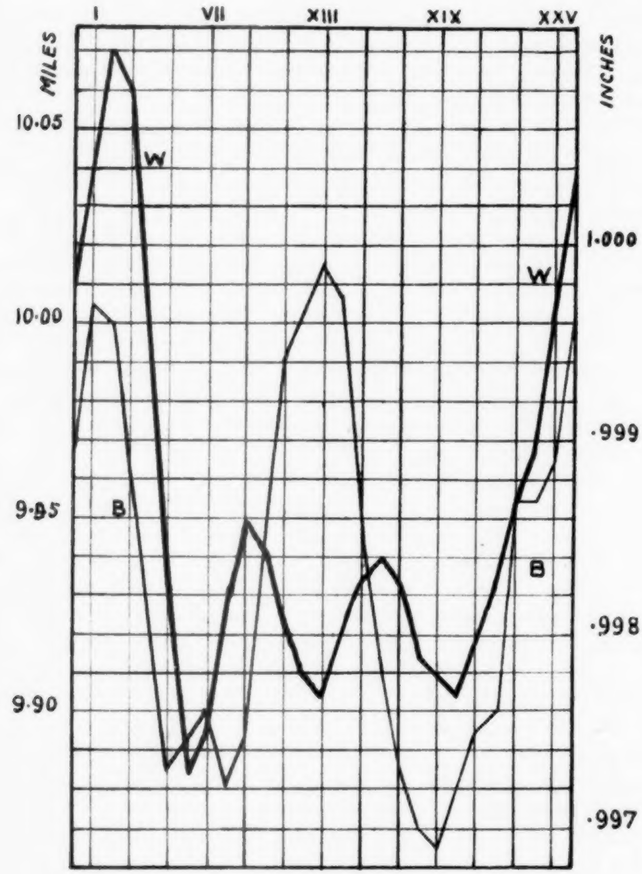
The displacement of the U.M.P. maximum forwards and backwards in time on the various curves is evidently largely a result of the general rise or fall of pressure level during the lunar day.

Wind Analogues.*

(*a*) A comparison between columns 7 and 8 is shown in the open-

* See the second and third papers.

scale diagram. Both curves agree in the main, but with two important exceptions: First, that the moon-rise maximum of pressure is not reflected in the wind curve; and next, that the wind velocity reverses to a minimum



Air pressure (B) and wind velocity (W) during the lunar day.

at U.M.P. Both curves end the day at a lower level than they began it, and both show a small irregularity at XXIII. It is evident, as pointed out in the previous papers, that the lunar influence upon the velocity of the wind cannot be exerted in a simple way through the medium of the air-tide,

The whole range of velocity is nearly 0·2 mile an hour, its relation to the whole range of pressure being 62 miles to 1 inch.

(*b*) The results of the previous paragraph are emphasised in a comparison between the mean perigee curves of wind and pressure; and, besides, the XXIII asperity is strongly marked on the wind curve.

(*c*) Just as the moon-rise maximum and the asperity at XXIII are faintly marked on the pressure curve at apogee, so are the moon-rise minimum and the asperity of velocity. The turning-points on the apogee wind curve lag somewhat.

(*d*) The noon perigee curve of velocity also shows a large general rise. The smoothing of the curve, however, has intruded a fall after XXIII. Had this been done with the pressure curve the values at XXIV and XXV would have been 1·0027 and ·9998 instead of 1·0354 and 1·0070 respectively, and the asperity at XXIII would have been merged into the L.M.P. maximum, as it is in the case of the wind.

(*e*) The slackening of velocity after the moon has crossed the meridian during midnight perigee corresponds to the large fall of pressure. The break in the fall of pressure at moonset which carries the minimum on to between XX and XXI is matched by the irregularity of velocity between XIX and XXI.

(*f*) At "horizon" perigee the large general fall of velocity is marked, and it enhances the moonset minimum. The wind curve bears the same kind of relationship to the pressure curve in this case as it does in general.*

(*g*) The small asperities of pressure in the nature of tiny maxima occurring near moonset are not represented in the velocities.

Note.—In the diagram the ordinates of the pressure curve are taken at clock hours, those of the wind apply to the middle of whole hours.

The Tropical Month.

As a matter of interest rather than in the expectation of obtaining any important relationships, the mean daily velocities have been compared with the mean daily pressures during 255 tropical months. The results, smoothed in threes, are shown in Table II, in which column 2 gives for periods of twenty-seven days (of which the fourteenth day is that of the moon's greatest south declination) the mean barometric pressure of each day in inches, and column 3 the corresponding mean daily velocity of the wind.

* Better analogies would probably be obtained from a comparison of (*e*) and (*f*) if each of the curves were to be subdivided into two, one giving particulars for the hours between II and X, and the other for the hours between XIV and XXII. A longer series of observations would be required for the discussion however.

TABLE II.—*Mean Daily Pressure and Air Movement during the Tropical Month.*

Day.	Pressure (inches).	Velocity (miles a day).
1	26·125	125
2	26·126	125
3	26·128	124
4	26·130	126
5	26·133	128
6	26·136	128
7	26·135	126
8	26·134	125
9	26·132	125
10	26·131	125
11	26·131	125
12	26·132	126
13	26·132	127
S	26·135	126
15	26·138	123
16	26·139	123
17	26·135	124
18	26·132	124
19	26·130	124
20	26·133	122
21	26·136	121
22	26·137	121
23	26·135	121
24	26·134	121
25	26·134	121
26	26·131	122
27	26·125	123
Month	26·132	124

The barometric curve has three crests, the principal one falling about two days later than the day of the moon's greatest south declination, the two others (which are almost as great) coinciding with the moon's passage north or south of a parallel lying a little north of the equator. The total range of pressure in the month is ·014 inch in smoothed values and ·019 in unsmoothed. The equatorial crests rise ·004 inch above the mean line. Pressure when the moon is going north exceeds that when it is going south by about ·003 inch.

Quite a hundred years of observation would be necessary to give equally trustworthy wind values, but three crests seem also to be indicated,

diminishing in magnitude and falling progressively earlier, counting from greatest north declination, than the pressure crests. In general the velocity is two miles a day above the mean when the moon is coming south, and two miles a day below the mean for the rest of the time. If there be a tidal connection between the pressure and the velocity of the air during the tropical month, it cannot be a very direct one.

Luke Howard devoted a good part of his time to an attempt to connect the moon's motions with changes of atmospheric pressure. By dividing the days of the year, for twenty-seven years, into periods of about seven days each,

> "the middle day of each week corresponding (1) with the moon's position coming north from the equator; (2) with her position in full north declination; (3) with her position returning to south over the equator; (4) with her full south declination,"

he obtained the following averages by means of a "clock barometer":

N.	29·782 inches
Equator	29·777 ,,
S.	29·774 ,,
Equator	29·792 ,,

Howard's interpretation of these numbers was that—

> "the barometric mean in our climate (England) is depressed (on an average of years) by the moon's position in south declination. . . . We have here, I think, evidence of a great tidal wave or swell in the atmosphere, caused by the moon's attraction, preceding her in her approach to us, and following slowly as she departs form these latitudes." *

* Papers on Meteorology, 1854.

DETECTION OF INDUCED BETA-RAY EMISSION FROM SUBSTANCES EXPOSED TO RÖNTGEN-RAYS BY A PHOTOGRAPHIC METHOD.*

By Lewis Simons, B.Sc.Lond.,

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(With Plate XIV.)

Desiring to overcome the difficulty of having to take very many electroscope readings in the study of the speeds of β-particles emerging from atoms exposed to Röntgen-rays, I have attempted to record the particles photographically. The present paper deals with the preliminary results.

C. T. R. Wilson was the first to photograph the images of the tracks of these β-particles by means of his cloud experiments; but in the present work, as in the case of the photographic study of the emission of β-particles from radioactive substances,† the particles themselves fall upon the photographic plate and produce an impression.

In some work that I hope to publish shortly an account is given of the manner in which the speeds of emergence of β-particles from ten different heavy atoms differ when exposed consecutively to two types of Röntgen-rays of wave-lengths $0{\cdot}56 \times 10^{-8}$ cm. and $0{\cdot}38 \times 10^{-8}$ cm. The ultimate object of this work is to determine these differences photographically. It was found that a copious β-radiation was emitted by a film of red-lead lightly dusted on to a slab of paraffin wax, and that when it was exposed to the Röntgen-rays of the shorter wave-length, the most rapid and normally directed particles moved over a maximum distance in atmospheric air of about $1{\cdot}0$ cm. This maximum range is given by the two expressions $\frac{1}{2}mv^2 = h\nu$ and $v^4 = ad$, where m is the mass of an electron ($8{\cdot}8 \times 10^{-28}$ gm.), h is Planck's constant ($6{\cdot}56 \times 10^{-27}$ erg. sec.), ν the frequency of the incident Röntgen-rays giving rise to a maximum speed of emergence v of the particle from the atom, d the range in normal air, and a a constant for

* The expenses of this research are partly covered by a grant from the Union Government through the Research Committee of the Advisory Board of Industries and Science of the Union of South Africa.—L. S.

† *e. g.* see the reproduction of Hahn's photographs in 'Rutherford's Radioactive Substances and their Radiations' (1913), figs. 70 A and B.

air* lying between 1×10^{40} and 2×10^{40}. These numbers fix the dimensions of the apparatus needed, and fig. 1 represents the first arrangement adopted in order to secure a direct β-particle photograph. A "slit" of Röntgen-rays 1·5 mm. broad coming directly from the tungsten anticathode of a Coolidge tube fell upon the red-leaded surface of the wax slab AB placed at an angle of 6° to the surface of the photographic plate CD, the beam of Röntgen-rays being carefully "sighted" in a preliminary experiment so as to ensure that it did not touch the photographic plate, but ran parallel to its surface at a distance of about 0·2 cm. from it. At X and Y the red-lead was removed from the wax along two broad lines. This was done as a control, for paraffin wax emits no β-particles. The plates used were "Imperial Special Rapid," the exposure was for five minutes with 7 ampères in the primary of a Newton-Apps 10-in. coil, the tube backing up a parallel spark 3 in. in length between balls. The resulting photograph is shown in register in fig. 2, and shows unmistakably that the impression has come from the red-lead film opposite. These photographs are positives, a darkening representing absence of photographic action. The line Y is not clearly seen because it was much narrower than X, the diffusion of the particles from surrounding regions rendering it invisible, and it probably fell on the edge of the incident beam.

In order to find how much of the effect is due to the diffusing β-particles or to the secondary Röntgen-rays from the red-lead, a cross of paraffin wax 0·005 cm. in thickness and one of mica 0·00136 cm. in thickness were stuck on to the photographic plate with a touch of glue (shown by the black spots in the middle of the crosses, fig. 3) in the region directly opposite to that part of the red-lead surface acted upon by the Röntgen-rays. The resulting photograph shows in a striking manner that of the two influences it is the β-radiation that produces the photographic impression, the photographic plate being effectively shielded by so small a mass of substance, far too small to be effective in stopping a Röntgen-ray beam properly so-called. The red-lead surface was about 0·35 cm. above the wax cross and 0·5 cm. above the mica one.

A preliminary experiment was now performed in order to determine the maximum range at which these particles could produce a photographic impression. Using the same arrangement as above, the angle between the slab and the photographic plate was doubled, and the whole system shifted laterally with respect to the incident beam of Röntgen-rays by intervals of 1 mm., allowing a 3-minute exposure at each shift. In this manner practically the whole length of the red-leaded surface was exposed to the rays. In order to show up any effect on the photographic plate opposite, this was covered by a perforated strip of tissue paper 0·0034 cm. thick, absorbing no Röntgen-rays falling on the plate but effectively stopping any β-particles. On the negative itself, fig. 4, the strip is visible right to the

* Bohr gives $1{\cdot}1 \times 10^{40}$, 'Phil. Mag.' (6), xxv, p. 28, 1913. Whiddington $2{\cdot}1 \times 10^{40}$, 'Proc. Roy. Soc.' (A), lxxxvi (1912), p. 370.

end of the plate, in which region the red-lead surface was at an approximate distance of 2 cm. from it. Particles must therefore have traversed this distance in normal atmospheric air. Part of the impression must be due to β-radiation from the air itself, although fig. 2 shows that it cannot be very much. The limiting radiation from the Röntgen-ray tube will be tungsten "K" radiation of wave-length about $0 \cdot 2 \times 10^{-8}$ cm. Using this value and a rough average value, say $1 \cdot 5 \times 10^{40}$, for Whiddington's absorption constant "a," the value of d, the maximum range in air of the β-particles should be about 3·3 cm. As a matter of fact it is not easy to obtain the limiting rays from the tungsten anti-cathode, and I do not think they were present in the mixed beam falling upon the red-lead.

Figs. 5 and 5A are perhaps of more general interest. In this and in several other similar experiments it was found that if the red-lead surface be replaced by a photographic plate the silver salts themselves give rise to a copious supply of electrons in the same manner as the lead, affecting another photographic plate at a considerable distance from the first. Fig. 5 shows the direct impression of the beam taken in the same manner as fig. 4, and fig. 5A shows the effect on the opposite plate upon which no direct Röntgen-rays fell. In fact, a similar effect would be given by any element of high atomic weight.

It is interesting to note that Sir W. H. Bragg* states that it is these electrons with which I have been dealing which cause the chemical action in the emulsion of a photographic plate when an ordinary X-ray photograph is taken in the usual manner. The number of particles and therefore the photographic effect can be increased by loading the film with a lead compound. Some experimenters have laid a thin sheet of lead on the film so that electrons generated in the considerable absorption of X-rays by the lead may strike back on to the photographic plate. These particles will traverse only the thinnest films of solid, and we are bound to conclude from the study of these photographs when one examines the relative impressions due to β-particles and Röntgen-radiation from the same mass of substance, the latter being comparatively non-existent, that the latent image on a photographic plate, whether caused by ordinary light or X-rays, is inseparably associated with the ionisation of the molecule. By ionisation is meant the separation of one electron from the molecule. X-rays are ineffective on a photographic plate until the energy has been converted in the production of electrons; these are the effective agents. When X-rays traverse a gas, the first act is to produce comparatively high-speed electrons which spend their energy in ionising local molecules. There is no reason to suppose that the process is different when X-rays are absorbed by a solid, such as, for example, the photographic film, except in that the range of action of the electrons is more limited.

* 'Trans. Faraday Soc.,' xv, pt. 2, 1919; "Symposium on Radiometallography," p. 30.

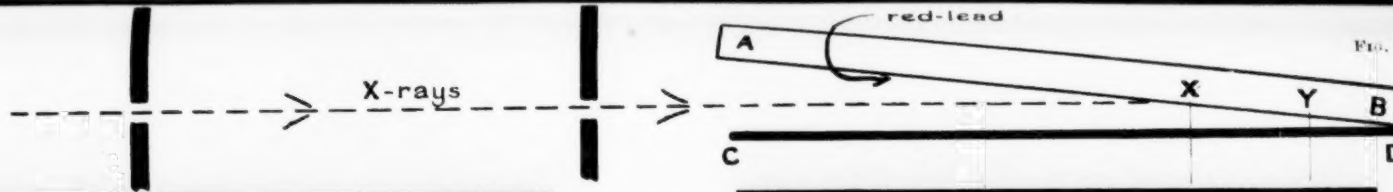

Fig. 1.

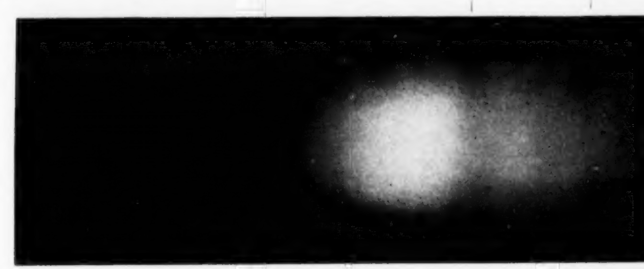

Fig. 2.

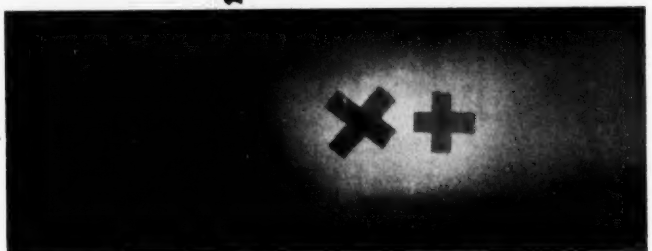

Fig. 3.

MICA

WAX

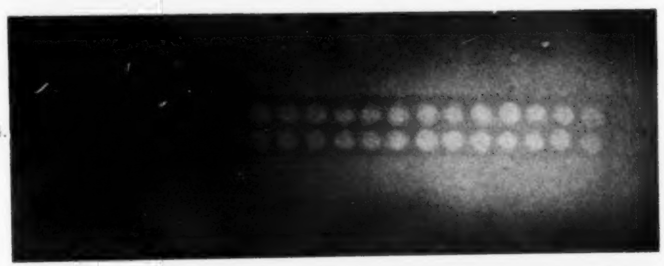

Fig. 4.

Fig. 5

Fig. 5A.

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EXPERIMENTAL INFESTATION OF FRESH-WATER SNAILS.

By F. G. Cawston.

A relatively small number of fresh-water snails kept under artificial conditions do not thrive well for any length of time. Their development would seem to depend on warmth, sunlight, and the supply of appropriate food. Water-cress is very useful for the supply of the minute organisms on which snails feed.

On several occasions I have secured the adult Schistosomes from animals supplied with cercariae developing in *Physopsis africana* in some of the rivers and stagnant pools of Natal. I have also secured *Fasciola gigantica* from a guinea-pig which had eaten the encysted cercariae I had obtained from *Limnaea natalensis* in a pool at Sydenham, in the Durban suburbs. I was therefore interested to determine whether I could obtain the same cercariae in specimens of these two fresh-water snails which had been bred from eggs and kept free from all possible sources of infestation except from the eggs of *Schistosoma haematobium* and *Fasciola giganticum*.

In some instances I obtained the eggs of *Limnaea natalensis* and other fresh-water snails from wild water-lilies. But I usually obtained the eggs from a jar of water in which I had placed adult snails, so that I could be sure of the date on which they were laid, and determine how fast the various species developed under artificial conditions. I found that during the fourth month the various species had developed sufficiently to be exposed to possible infestation.

On January 7, 1920, I placed 60 *Limnaea natalensis* which I had bred from eggs and kept free from all sources of infection in a jar of water containing fasciola from a sheep's liver. The snails were allowed to crawl over the flukes, and possibly devour their eggs for most of the day. On January 15, eight days later, all were dead.

On January 16, 30 *Limnaea natalensis*, also bred from eggs and kept free from infection, were placed in a jar of water containing 3 *Fasciola hepatica* and their typical ova from a sheep's liver.

On January 24, only eight days later, an immature cercaria with a relatively large head and slender tail was seen amongst the eggs of one of these Limnaeae; many other cercariae without tails were also seen in a young sporocyst in the liver-substance of the snail. This was the only

snail in which cercariae were noted, and repeated attempts to infest *Limnaea natalensis* from miracidia escaping from the ova of *Schistosoma haematobium* have uniformly proved negative.

Limnaea natalensis is by far the most common snail that I have found in various parts of Natal, the Transvaal and the Cape. It has also proved the most easy to breed. In visiting an infected pool I have repeatedly found that only the most mature snails harbour the various cercariae for which I am looking; however, I have sometimes come across a very young Physopsis harbouring the Bilharzia, and have found the infection present in a Physopsis which was only 13 mm. in length.

On April 20, 1920, I placed 5 very young Physopses which I had bred from eggs in water containing the miracidia of *S. haematobium*. These snails were only 6 to 8 mm. in length, and showed no evidence of cercariae at the end of six weeks. They were probably too young to ingest the miracidia.

Several *Physopsis africana* which had also been bred from eggs and safeguarded from other infection were placed in water containing the miracidia of *S. haematobium* on February 21, 1920. Six weeks later, on April 2, the mature cercariae of *Schistosomaum haematobium* were present in these snails. Other Physopses similarly treated on February 21 showed the presence of similar cercariae on April 12, or eight weeks later, whilst 15 Physopses used as controls, and not exposed to miracidia, showed no infestation on April 28. They were about three and a half months old.

On January 6, 10 and 12, 26 Physopses which had been bred from eggs were exposed to water containing the miracidia of *S. haematobium*. On January 31 three contained very young sporocysts and cercariae, three were free from cercariae, and ten were dead. On February 13 mature cercariae, resembling those of *S. haematobium*, were present in two specimens. Some of these sporocysts and cercariae were submitted to Dr. R. T. Leiper, who states, "The sporocysts and cercariae from Physopsis would appear to be those of Schistosoma."

On February 13 and 16 about 20 Physopses were exposed to infection with the centrifugalised deposit of urine containing the typical spine-pointed eggs of *Schistosoma haematobium*.

On March 23 two were dead, but one contained a dark, branching sporocyst throughout the liver-substance, whilst the other contained a branching sporocyst with an immature cercaria possessing head, tail and prongs. On March 31 the typical Bilharzia cercaria was present in ten of these Physopses.

Three of these Physopses were only 7 mm. long, two only 7·5 mm. long, and one only 6·5 mm., showing that *Physopsis africana*, when only about four months old, is capable of harbouring the Bilharzia parasite

and of spreading infection in rivers. On March 26 four of these snails were dead, but each appeared to harbour sporocysts in their liver-substance.

On April 12 no cercariae were present in *Isidora tropica* and *Isidora forskali* which had been bred from eggs and exposed to the same miracidia on February 21.

I have demonstrated Bilharzia infection in some 30 distinct Physopses four to six weeks after exposing them to the miracidia of *S. haematobium*. These snails have been bred from eggs, and kept in tubs or jars of water removed from all sources of infection other than that due to experimental intervention.

SOME NOTES ON ANCIENT IDEAS CONCERNING THE DIAMOND.

By J. R. Sutton.

Scholars have devoted much time to the elucidation of the probably large substratum of truth that underlies ancient fables and fancies about the diamond. And scholars of future ages may perhaps be equally industrious in trying to explain the fables and fancies of our own time on the same subject.

One of the most competent of recent discussions of ancient ideas about the diamond is Berthold Laufer's 'The Diamond: a Study in Chinese and Hellenistic Folk-Lore'*; and the following notes are in the nature of a running commentary on his work. I say "competent" in an observational sense; the philology is, of course, beyond me. He establishes the curious fact that although India was the distributing centre of diamonds to Hellas and Rome† on the one hand and to China on the other, the ideas conceived by the Chinese regarding the diamond do not coincide with those entertained in India, but harmonise with those which we find expounded in classical literature.

1. Legend of the Diamond Valley (p. 6).

This legend is adapted in "Sinbad the Sailor," and is an abridged form of a well-known western story, of which the oldest known version is contained in the writings of Epiphanius, *circa* 315–403. The various stories described under this head coincide in general in the fable of a deep and inaccessible valley whose floor is strewn with diamonds. Flesh is thrown into the valley from above; the diamonds adhere to it; the eagles hovering about scent the flesh, pounce down upon it and carry it to their eyries, where the diamonds are recovered—from the droppings, as some writers relate.

The author gives his opinion that the story originated in the Hellenistic Orient, and was probably invented there for the benefit of foreign traders. And he regards it as belonging to the same type of legend as that related by Herodotus in 'Thalia' of the manner in which cinnamon was obtained by the Arabs.

* Field Museum of Natural History. Publication 184, 1915.

† Dieulafait in 'Diamonds and Precious Stones,' 1874, accepts the tradition that "the diamonds earliest known to the Romans were furnished by Ethiopia."

A prosaic motive for the story can perhaps be furnished from Kimberley experience. It is said that in the early days of Kimberley the breeding of poultry was a profitable business, for the birds wandering at large over the *débris* from the mines always picked up and swallowed the small diamonds they saw, and the crop of every fowl slaughtered in the place was carefully searched in consequence. Some years ago I saw a diamond of about half a carat which was stated, on the good authority of the owner, to have been taken from a fowl's crop. On one occasion twenty-three diamonds, weighing $5\frac{1}{2}$ carats altogether, were found in the crop of a pigeon which had been shot on the De Beers depositing floors. Ostriches are known to swallow pieces of glass and stone and various bright minerals, and the fact has been invoked to account for the sporadic finds of diamonds along the Orange River.* Strip the legends of their romantic accretions and there is no great difference between them and things that happen. Now that the mining area is enclosed and there is not very much unwashed kimberlite *débris* left people do not bother so much about opening a fowl's crop, but plenty of small garnets and zircons can still be found that way.

In a footnote to the chapter on the "Legend" (p. 16) the author remarks that "The knowledge of the diamond certainly does not go back in India into that unfathomable antiquity as pretended by some mineralogical and other authors. It was wholly unknown in the Vedic period, from which no specific names of precious stones are handed down at all. The word *mani*, which has sometimes been taken to mean the diamond, simply denotes a bead used for personal ornamentation and as an amulet, and the arbitrary notion that it might refer to the diamond is disproved by the fact that it could be strung on a thread." As to that, possibly the notion is an arbitrary one, like many other statements concerning the diamond; nevertheless, natural diamond beads are sometimes found. My own collection, for example, contains a dozen "strung on a thread." One way in which these natural beads can be formed depends upon the fact that diamond crystallises readily about various foreign minerals, such as ilmenite, garnet, zircon, diopside, olivine, iron pyrites,† graphite, etc. When these foreign minerals are not completely enclosed they may often be easily removed or they may drop out of themselves, leaving a hole sometimes extending right through the diamond. The readiness with which diamond crystallises about foreign minerals acts, indeed, to its own hurt, for the inclusion, if complete, invariably cracks the diamond sooner or later, giving rise to the frequent

* *E.g.* "the possibility of the existence of diamond deposits near the junction of the Orange and Vaal was flatly denied by a pretentious examiner who came from England to report on the Hopetown field. It was gravely asserted that any diamonds in that field must have been carried in the gizzards of ostriches from some far-distant region." G. F. Williams, 'The Diamond Mines of South Africa,' p. 122, 1902.

† The "leaf of gold" said to have been seen in the centre of a beautifully crystallised Brazilian diamond may have been pyrites or mica.

cleavage fragments. Another, though rarer, way in which a natural bead can be formed may arise when a number of diamonds crystallise in a cluster. Suppose, *e. g.*, that two diamonds grow corner to corner (as they often enough do), and that a third grows round the contact. If, then, in the mining or winning they should fall apart the third will appear as a bead. This second way gives the most elegant beads. Not that it is essential that a diamond should be bored through in order that it may be strung on a thread, for it might be mounted on a metal bead. By way of illustration, "it is no uncommon sight to see the natives of Borneo wearing waistcoats ornamented with gold buttons, in each of which a diamond is set." *

In the same footnote is the following: "S. K. Aiyangar calls attention to the fact that the first systematic reference to diamonds is made in the Arthaçāstra of Kauṭilya. He mentions six kinds of diamonds classified according to their mines, and described as differing in lustre and degrees of hardness." It is not clear whether this is really intended to mean that different Indian localities produce different types of diamond, or whether it refers to their grading, named after the castes, as Brahmins, Kshatriyas, etc., just as cut diamonds to-day are classed as Rivers, Jagers, Wesseltons, etc., according to their quality, and irrespective of their proper source. It is well known, of course, that diamonds have a local individuality, and the fact has an important bearing on the problem of their origin. As the accurate John Mawe told us more than a century ago, "The mineralogist who has been in the habit of seeing and accurately examining numerous specimens of this gem acquires a kind of tact that enables him to distinguish at once and with little risk of mistake a *bolsa* of stones from Hindostan, and a similar one from Borneo, or from the Portuguese territories in South America; nay, even the diamonds furnished by one part of the Serro do Frio may be discriminated from those of other parts of Brazil, or even of the same district. But these characters, although sufficiently visible to the experienced eye, are too evanescent to be restricted within technical description, and are as yet entirely unknown to the commercial dealers in precious stones." †

In the same way no person of experience would mistake the source of a parcel of South African diamonds won from one spot. The production of one mine is not like that of any other.‡ An individual stone may be of doubtful origin sometimes; *e. g.* a particularly sharp-edged glassy octahedron from Bultfontein might, seen alone, be mistaken for a Monte Leo stone; but the source of half-a-dozen Bultfontein glassies, taken as they come, would not be in doubt. So experts might differ as to whether

* G. H. Smith, 'Gem Stones,' 1912, p. 155.

† 'A Treatise on Diamonds and Precious Stones,' 1815, p. 32.

‡ And this is true not only of the diamond, but also of the other minerals forming the kimberlite matrix.

one given "rounded" octahedron belonged to Wesselton or Dutoitspan, albeit they would not differ about a number.

2. Indestructibility of the Diamond (p. 21).

Two cognate stories are given under this head, one from Pliny and the other from Ko Hung (fourth century A.D.):

"Pliny sets forth that the indomitable power which contemns the two most violent agents of nature, iron and fire, is broken by the blood of a ram [? billy-goat, 'hircino'], which, however, must be fresh and warm. The stone must be well steeped in it, and receive repeated blows, and even then will break anvils and iron hammers unless they be of excellent temper."*

According to the Chinese version, "The kingdom of Fu-nan (Cambodja) produces diamonds which are capable of cutting jade. In their appearance they resemble fluor spar. They grow on stones like stalactites, on the bottom of the sea to a depth of a thousand feet. Men dive in search for the stones and ascend at the close of the day. The diamond when struck by an iron hammer is not damaged; the latter, on the contrary, will be spoiled. If, however, a blow is dealt at the diamond by a ram's horn [according to another reading, 'antelope or chamois horn,'] it will at once be dissolved and break like ice."

Pliny may have read the property of toughness into what he had heard of the hardness of diamond. Diamond is anything but tough, and even carbonado, to say nothing of bort, is easily shattered by a blow. Careless handling in steel forceps will chip the edges of brilliants. The Chinese account is evidently a promiscuous mixing of the properties of calcite, quartz, pearl and diamond. But the great hardness of diamond has been exaggerated in modern times. Thus no less a philosopher than Sir John Herschel could describe diamond as "almost infinitely harder than any other substance in nature,"† a statement whose inaccuracy could have been rectified by a reference to Mawe's Treatise then in circulation. Mawe said, acutely enough, that "We know in general that, when two substances, greatly differing in hardness, come into collision, the effect produced by each upon the other is nearly in the ratio of their respective degrees of hardness; the softer one will undoubtedly be the most affected, but the hardest will by no means escape unhurt. . . . With regard to the diamond we have the most authentic testimony that the Chinese and East Indian lapidaries are in the habit of polishing it upon a piece of corundum, the hardness of which is greatly inferior to that of the gem."‡ Even Mawe's

* A newly-rich visitor to the diamond fields knew better: "My 'usband says diamonds are not so 'ard as people say; for 'e put some of mine on a hanvil and 'it 'em 'ard with a 'ammer and smashed 'em hall to hatoms."

† 'Preliminary Discourse on the Study of Natural Philosophy,' 1830, p. 237.

‡ P. 20. Diamonds have been cut and polished in modern times with the powder of crystallised boron—"with entire success" according to Dieulafait.

assertion that a diamond in his own possession had been so rolled and worn that not a single piece of its natural crystal surface remained has not deterred high living authorities from stating that diamond is seldom found " waterworn."

But is there not just a possibility that Pliny's assertion was founded on something more tangible than a mere confusion of the properties of hardness and toughness? Apart from the well-known fact that diamond would cut iron, is it not a fair guess that some ancient lapidary might have put a diamond into a vice, and so found that the iron might crush, but still suffer somewhat from, the stone?

Sir William Crookes, in the course of his magnificent lecture before the British Association in Kimberley in 1905, performed the experiment of squeezing a diamond into steel. Under the great hydraulic pressure employed (60 atmospheres) the diamond was seen, projected on the screen, to sink into the steel as if that were no more than butter.* While no ancient craftsman could have commanded the same power, it is significant that "Muhammed Ibn Mansūr, who wrote a treatise on mineralogy in Persian during the thirteenth century, says, regarding this point, 'On the anvil the diamond is not broken under the hammer, but rather penetrates into the anvil.'"

Concerning the Chinese account that diamonds are fished from the ocean, the author comments that is an old Indian fable; and in a footnote he adds that the Hindu mineralogists also entertain the notion that diamond floats on water. Yet, while the fable does confound pearls with diamonds, it is fairly certain that diamonds could be fished from the Atlantic off the coast of South-West Africa if the game were worth the candle. Moreover quite large fragments of diamond will float provided that their spread is great enough compared with their thickness. It is a simple and a very pretty experiment to float a flake of diamond on water, and then, glancing along the surface of the water, to see that the whole of the diamond is much below the general level—hanging suspended, as it were, in a bag from the surface.

I gather that the author favours an astrological signification for the blood and the ram's horn part of the stories. As in Gower:

> "The sterre ellefthe is Venenas
> The whos nature is, as it was,
> Take of Venus and of the Mone
> In thing which he hath forto done.
> Of Adamant is that perrie
> In which he worcheth his maistrie."†

But the handles of some of the lapidary's tools might have been of horn.

* This diamond, deeply embedded in the steel, is still preserved in the sorting office of the De Beers Company. The experiment may be imitated, more or less successfully, with an office letter-press.

† 'Confessio Amantis.' Bk. VII.

3. Diamond and Lead (p. 26).

The idea that diamond could be attacked and subdued by lead appears to have originated in Greece, and to have been adopted afterwards by the whole world. Underlying the idea the author works out the hypothesis* that diamond was wrapped in lead before being broken into engraving points, in order that none of the fragments should be lost. It may be added that diamond might have been put into a vice for the same reason. Mediæval writers introduced into the story something allegorical. Thus Philip de Thaun, in his Anglo-Norman 'Bestiary,'† *circa* 1130:

" E çes sacez vereiement que l'en l'adamas bruist en fent,
Par le sanc de buc e de plun, signefie grant raisun.
Seignurs, aez i entente, bucs est beste pulente;
Par le sanc de buc entendum en nostre lai corruptiun;
Par plum entendum peché par quei hom sunt enginné;
Ke li plums paise que fer, ki pechurs traite en emfer;
Corruptiun a pechet nus fent.] encontre Deus nus ofent.
E cel vertu ad en sei, le fer trait od sei;
Signefie que Christiens traient à la lur lei paens,
Quant il laissent lur eresie, e creient el Fiz Sanctae Marie."

[And this know truly that they break in pieces the diamond,
With goat's blood and lead, it signifies a great matter.
Lords, pay attention to it, a goat is a stinking beast;
By the blood of the goat we understand corruption in our law;
By lead we understand sin by which men are ensnared;
That the lead weights the iron which draws sinners to hell;
Corruption and sin splits us and makes us offend against God,
And this virtue it has in it, it draws the iron with it;
It signifies that Christians draw Pagans to their law
When they leave their heresy and believe in the Son of St. Mary.]

4. The Diamond Point (p. 28).

The only circumstance we shall notice under this head is the old and persistent idea of a mysterious association between diamond and iron.‡ This matter has been discussed in "Kimberley Diamonds, especially Cleavage Diamonds,"§ under the heading "Stewartite." Stewartite more than revives the idea of the same mysterious association, combining as it does the properties of diamond and loadstone. John Lyly, in 'Euphues and His England,' 1580, expresses the current conventional idea of his time concerning

* Suggested, perhaps, by modern practice in the cutting factories.

† Edited by Thomas Wright, 1841, p. 125.

‡ *Cf.* L. Pearsall Smith in 'The English Language,' N.D., p. 160: "*Phœnix*, the name of an imaginary bird, and *adamant*, used in literature to describe a half fabulous rock or crystal, combining the qualities of the diamond and the loadstone, were, with the earlier *drake* (dragon), the first of the names of the legendary animals and jewels to reach us from the East."

§ Sutton, 'Trans. Roy. Soc. S. Afr.,' 1918.

the *antipathy* between the loadstone (*adamant* in this case) and the diamond: "For as it is impossible for the best *Adamant* to drawe yron vnto it if the *Diamond* be neere it . . ." That there is no such antipathy is only a proof of the rarity of the diamond in Tudor times, and of the abiding influence of Pliny.

5. Diamonds and Gold (p. 35).

"Qazwīnī speaks of an amicable relationship between gold and the diamond, for if the diamond comes near gold, it clings to the latter; also it is said that the diamond is found only in gold mines."

Pliny mentioned a casual relationship, but in such a way as to lead to the inference that the similar crystallisation was implied, seeing that gold is indeed occasionally found in small octahedral crystals. As usual his followers copied him uncritically; and hence we have the Chinese compound *kin-kang*, which, the author argues, is traceable to classical antiquity, and really means "the hard stone originating in gold."

Diamond and gold are not found in association in the river diggings of Griqualand West, although some diamonds are obtained from the Rand banket.* The latter are nearly all green, varying from light bottle green to dark olive. The colour has been attributed to the action of radium, but some typical specimens tested by me showed no signs of radioactivity. In the clearer specimens of these the colour is seen to be derived from included streaks of green and yellowish-brown foreign matter much too dense to be due to finely divided gold. Mawe reported some very fine superficially green diamonds from Brazil. Occasional superficially green diamonds are found in the Kimberley area, and now and then one meets with olive green laminated stones in Koffyfontein; also diamonds from the Eland mine have a faint greenish cast, none of these being now associated with gold, if they ever were. The genetic relationship between diamond and gold is clearly not so intimate as that between, say, diamond and magnesium, to some combination of which the coloration of diamond may hypothetically be ascribed.

That Pliny, when he spoke of adamas as a name given to a crystal of gold, was only referring to outside appearances, seems to be proved by the six sorts of adamas which he cites as coming from various localities; for evidently he was quite aware that not all these had the same physical characters. He was no more in error than the jewellers who sell Scotch Topaz, Cape Ruby, Water Sapphire, Cornish diamonds, etc., nor than the mineralogists, who call a diamond macle a "spinel twin." And he has not perhaps been always happy in his translators. Bostock and Riley render his "sexangulo" by "hexangular and hexahedral,"† Boutan by "six côtés."

* See R. B. Young, 'The Banket,' 1917, p. 35.

† "No body, of course, can simultaneously be hexangular and hexahedral, the hexahedron being a cube with six sides and four points"! (Laufer, p. 44).

6. Imitation Diamonds (p. 41).

The author quotes the following from the 'Agastimata': "When a connoisseur believes that he recognises an artificial diamond, he should test it by means of acids or vinegar, or through the application of heat: if false it will lose colour; if true it will double its lustre." Chinese authorities echo the same advice.

Neither the acids known to the ancient Indian or Chinese chemists, nor heat, would be sufficient in every case to detect a false stone, especially if it be colourless. The colour of South African zircons is easily removed in the flame of a spirit lamp, and this test is decisive as regards fragments of zircon and diamond of the same yellowish-brownish colour, which are not easy to discriminate by the eye. In general the hardness and specific gravity will decide. Acids (and sometimes the flame), by removing coatings of foreign matter, improve the appearance of some rough diamonds amazingly. Parcels of South African diamonds are always cleaned in acid (hydrofluoric or aqua regia) and spirits of wine before being sorted for shipment to Europe.

7. Stones of Nocturnal Luminosity (p. 55). Phosphorescence of Precious Stones (p. 63).

The author inclines to the opinion that the various Greek and Chinese legends of night-shining gems do not necessarily prove that the phosphorescence of the diamond was a recognised phenomenon: "Altogether we have to regard the traditions about gems luminous at night, not as the result of scientific effort, but as folk-lore connecting the Orient with the Occident."

One would be inclined to doubt, in fact, whether, if the property of phosphorescence had not been established, anyone at all would have read into the accounts that have come down anything more than a mere fairyland exaggeration of the light-catching power of diamond. It is remarkable how strongly a cut diamond seems to catch stray feeble rays at night, even starlight, when other gems remain obscure. Some rough diamonds have the same property, though in a much less degree.

Phosphorescence, contrary to belief,* is not a general property of diamonds. I have examined a hundred or more Kimberley diamonds (after having exposed them to sunlight) without detecting it. Le Bon exposed about a hundred diamonds, said to be one half Brazilian and the other half Cape, to the illumination produced by burning magnesium, and found that "nearly all the Brazilian and all those of the Bahia mine were, during the

* "They say the proof of a true diamond is to glitter in the dark" (Dryden's 'Amphitryon,' III). "E çeo dit Phisologus que adamas ad vertut plus . . . pur nuit gete grant luur" (P. de Thaun).

operation, brightly phosphorescent, as much so as an isolated fragment of sulphide of zinc. Not one of the Cape diamonds was phosphorescent. The non-phosphorescence of the Cape diamond is, however, not absolute, for after one has remained in the dark for at least twenty minutes in order to rest the eyes . . . a very slight phosphorescence on nearly half of them is detected. This phosphorescence is on the border of the perceptible minimum of light."* Le Bon attributes phosphorescence to the presence of infinitesimal proportions of certain foreign bodies. He claims that Bahia diamonds are worth 40 per cent. more than Cape diamonds, apparently meaning those of one colour and size: "Cape diamonds, often as colourless as those of Brazil, and sometimes larger, are always very inferior to the Brazilian, not only by their hardness but also by their brightness." If this statement were true—and it wants a deal of proving—we should have to admit that the superior qualities of the Brazilian stones arise from the presence of impurities. "Sometimes larger" is good. Crookes, in his Kimberley lecture, remarked that "some diamonds are fluorescent, appearing milky in sunlight. In a vacuum, exposed to a high-tension current of electricity, diamonds phosphoresce of different colours, most South African diamonds shining with a bluish light. Diamonds from other localities emit bright blue, apricot, pale blue, red, yellowish-green, orange, and pale green light. The most phosphorescent diamonds are those which are fluorescent in the sun. One beautiful green diamond in my collection, when phosphorescing in a good vacuum, gives almost as much light as a candle. . . . Diamonds which phosphoresce red generally show the yellow sodium line superposing on a continuous spectrum. In one Brazilian diamond phosphorescing a reddish-yellow colour, I detected the citron line characteristic of yttrium."

In the remarkable mixture of truth and error contained in the old writings discussed by Laufer it is not altogether improbable that the language was framed, in the first instance, to hide trade secrets, and with deliberate intent to deceive. The persistence of the stories was only an aspect of the dominion of classical literature over the thought of the middle ages, and, moreover, the guild interests of lapidaries and alchemists were concerned in keeping the half truths and errors alive. The alchemists knew a good deal more, no doubt, than they told to outsiders. Soddy, indeed, has argued that they knew something about radium.

* 'The Evolution of Forces,' 1908, p. 233.

A STUDY OF THE *B. COLI* GROUP WITH SPECIAL REFERENCE TO THE SEROLOGICAL CHARACTERS OF THESE ORGANISMS.

By T. J. Mackie.

Introductory Discussion: The Classification of "Coliform" Bacilli and the Biological Relationships of the *B. coli* Group to other Gram-Negative Aërobic Intestinal Bacilli.

In 1885 Escherich recorded the isolation of a Gram-negative intestinal bacillus which he designated *B. coli communis*, and this classical type has been long considered the prevalent intestinal bacterium. In general this organism has been described as a motile, non-sporing, aërobic, facultatively anaërobic, Gram-negative bacillus, which grows at 37° C., ferments glucose, lactose and dulcite with acid and gas production, forms indol from peptone, clots milk, reduces nitrates, and grows in gelatin media without producing liquefaction.

With the advance of bacteriological knowledge and as a result of extensive investigations on the bacteriology of faeces, water, milk, etc., this original type has come to represent only one of a considerable bacterial class or group. The organisms of this group, however, are characteristic normal inhabitants of the animal intestine, and are therefore conveniently designated by the generic term *B. coli*.

Their pathological importance has been well established in virtue of their potentially pathogenic properties, and in the bacteriological diagnosis of intestinal infections their precise recognition and the separation and differentiation of specific pathogenic organisms from them have necessitated the most careful study of their biological characters. Moreover their occurrence in water supplies has led to an extensive study of the whole group from the point of view of sewage contamination, and the importance of certain types as indicators of such contamination has been emphasised. Thus, the detection of these organisms constitutes an essential method in the routine examination of water supplies. This group of bacteria is also concerned in the process of souring of milk, and certain of the classical types were originally isolated from this source, *e.g. B. acidi lactici* (Hüppe).

While the whole group of organisms biologically allied to Escherich's

original type has been classified as *B. coli*, the question as to which varieties represented "typical" *B. coli* as apart from "atypical" forms has been studied in connection with the bacteriology of water (Houston and others). Much confusion has resulted, however, as regards the definition of a typical *B. coli* owing to the different identification standards set up by various observers. Some of these definitions have been too limited in their application and different degrees of importance have been attached to different characters (Savage, Prescott and Winslow, Konrich, Reports of the English and American Committees on standard methods for the examination of water).

While there has been considerable variation in the criteria adopted by different workers for the identification of the colon bacillus, the characters generally accepted as common to the whole group of "*B. coli*" may be summed up as follows: Gram-negative, aërobic, facultatively anaërobic non-sporing bacilli growing at 37° C., and fermenting glucose and lactose. Other characters, *e.g.* different fermentative reactions, motility, indol production, Voges and Proskauer reaction, simply determine the differentiation of separate types. Thus the term "lactose-fermenter" has been frequently used as a convenient designation for the group (MacConkey).

The question arises as to whether gelatin-liquefying, Gram-negative bacilli which correspond in other characters to *B. coli* types are to be included in this biological group. Among the lactose-fermenters classified by MacConkey certain gelatin liquefiers were represented, *e.g. B. cloacae*, *B. oxytocus perniciosus*, and other authorities (Prescott and Winslow) have accepted this reaction as one of the possible characters of the group. In my own experience of a large number of coliform strains from faeces, urine, etc., and also water (Egypt, 1915–1918) I have never met with gelatin-liquefying, Gram-negative, aërobic, non-sporing bacilli capable of growing at 37° C. apart from those referable to the *B. proteus* type.*

While the characteristic *B. coli* has the property of fermenting lactose, it is doubtful (as will be shown later, p. 350) if lactose fermentation can be regarded as a specific character of a particular group of intestinal bacilli, and studies on the variation of these organisms (*v.* p. 360) have shown how certain types only acquire this property by mutation on culture medium.

Thus non-gelatin-liquefying, glucose-fermenting, non-lactose-fermenting bacilli of intestinal origin have to be considered in any system of classification of the Gram-negative intestinal bacilli.

From our present knowledge of the aërobic intestinal bacilli it would appear more rational from the purely biological standpoint to recognise a

* *B. proteus*: Gram-negative, motile, aërobic, non-sporing bacilli, growing well at 37° C., showing a tendency to "spreading" type of growth, fermenting glucose with or without gas, not fermenting lactose, dulcite or mannite, varying in fermentation of saccharose and in indol formation, liquefying rapidly gelatin or solidified serum.

large class of intestinal bacilli having the common characters: aërobic, Gram-negative, non-sporing, growing at 37° C., fermenting glucose with or without gas production, not liquefying gelatin; comprising certain specific pathogenic organisms specially designated, and identified by cultural and serological characters, *e.g. B. typhosus*, etc., and a large number of saprophytic, though potentially pathogenic, varieties which can be generally classified into different types according to their cultural characters. The term *B. coli* (if it is to be used at all) in its widest application would thus become referable to those members of the class which do not possess *specific* pathogenic properties irrespective of certain cultural characters, including lactose fermentation. The term "typical *B. coli*" would be used, if necessary, to designate those types (fermenting lactose, clotting milk, and producing indol) which are most prevalent in the intestine, and therefore undoubted indicators in water of recent sewage pollution. The only justification for recognising a special group of "lactose fermenters" depends on the statistical fact that these types are most prevalent in fresh animal excreta, but it is questionable if the statistical basis can be used for a biological classification.

The further question arises as to the significance of gelatin liquefaction, and whether a wider definition of the class is required, *i.e.* to include *B. proteus*. It must be admitted that with the exception of gelatin liquefaction, types of *B. proteus* may correspond closely to certain non-liquefying intestinal bacilli.

Organisms of the *B. faecalis alkaligenes* type have also to be considered in regard to the classification of the Gram-negative intestinal bacilli. *B. faecalis alkaligenes* has been long recognised as differing from the motile organisms of the coli-typhoid class in the "terminal" position of its flagella, as opposed to the "lateral" arrangement in the case of *B. coli* and *B. typhosus* (Berghaus, Klimenko). While this is true for my own observations of these organisms, non-motile, Gram-negative, aërobic bacilli which do not ferment glucose or any other sugar have been frequently noted in dysenteric stools, and strains of this type have been found which on first isolation did not ferment glucose, and only gained this property after a period of growth in a glucose medium. This might appear to link up organisms of the *B. faecalis alkaligenes* type with the sugar-fermenting intestinal bacilli.

The "lactose-fermenters" have been the subject of much careful study: originally different classical types had been separately described, *e.g. B. coli communis*, *B. neapolitanus* (Emmerich), *B. acidi lactici* (Hüppe), *B. lactis aërogenes* (Escherich), etc., and these names may still be retained for organisms which accurately correspond to such classical strains.

The work of MacConkey on the lactose-fermenting coliform bacilli represented the first attempt in the direction of a rational system of classification of these organisms.

A number of cultural tests had been commonly employed which were shown by him to be of little differential value, and he further established the importance of a selected though comprehensive series of biochemical reactions as type criteria.

MacConkey (1905), in his first paper dealing with this subject, arbitrarily divided the lactose-fermenters into four sub-groups according as they did or did not decompose saccharose and dulcite. The first group, represented by the classical *B. acidi lactici*, included those which fermented neither dulcite nor saccharose; the second included those which fermented dulcite but not saccharose, *e.g. B. coli communis*; the third comprised types such as *B. neapolitanus* which fermented both dulcite and saccharose; and the fourth consisted of strains which fermented saccharose, but not dulcite.

This classification was of course entirely arbitrary and incomplete.

In 1909 MacConkey reviewed the whole subject, and indicated that if, in addition to the fermentation of dulcite and saccharose, further tests were added—effect on adonite and inulin, presence of motility, indol production, the Voges and Proskauer reaction—theoretically 128 possible varieties could be differentiated. At that time he had examined 497 strains from human and animal faeces, water, etc., and of the 128 possible types had met with 36 varieties differentiated according to their action on (1) gelatin, (2) dulcite, (3) saccharose, (4) adonite, (5) inulin, in some instances, (6) inosite, and by (7) the presence or absence of motility, (8) indol production and (9) the Voges and Proskauer reaction.

MacConkey had at the same time tested a number of other fermentable substances which had been commonly employed, but indicated that no further information was to be obtained by the use of sugars, etc., such as galactose and laevulose, on which the various sub-groups had all the same effect; and in the case of quercite and erythrite found that practically none of his strains had any fermentative action. Out of 497 strains examined 178 were from human faeces, and of the various types noted the most prevalent were type No. 71, *B. coli communis*, and *B. vesiculosus* (see Table I).

MacConkey's system of classification has been supported and adopted by Bergey and Deeham, Clemesha and others, and modified by Jackson, who employed the reactions in mannite and raffinose as further differential characters.

Howe, on the other hand, claimed that motility, indol formation, mannite and dulcite fermentation were of little value for classification owing to the fact that, from the statistical point of view, these reactions showed no correlation with one another or with other criteria. Prescott and Winslow have also urged the value of the statistical basis for a biological classification, and that the characters of these organisms should be considered not independently, but in relationship to one another.

TABLE I. (*Quoted from MacConkey*, 1909.)

Type (MacConkey's classification).	Number of strains.	Motility.	Lactose.	Dulcite.	Saccharose.	Adonite.	Inulin.	Inosite.	Indol.	Voges and Proskauer reaction.	Gelatin.
No. 1	9	+	+	—	—	+	—	—	+	—	—
B. acidi lactici (Hüppe), No. 2	1	—	+	—	—	+	—	—	+	—	—
B. Grünthal, No. 4	8	+	+	—	—	—	—	—	+	—	—
B. vesiculosus, No. 5	33	—	+	—	—	—	—	—	+	—	—
No. 7	1	+	+	—	—	—	—	—	—	—	—
B. coli mutabilis, (Massini) No. 8	—	—	+	—	—	—	—	—	+	—	—
No. 33	—	+	+	+	—	+	—	—	+	—	—
B. coli communis, No. 34	37	+	+	+	—	—	—	—	+	—	—
B. Schafferi, No. 35	11	—	+	+	—	—	—	—	+	—	—
No. 67	1	—	+	+	+	+	—	+	—	+	—
No. 71	42	+	+	+	+	—	—	—	+	—	—
B. neapolitanus, No. 72	15	—	+	+	+	—	—	—	+	—	—
No. 74	1	+	+	+	+	—	—	—	—	—	—
No. 75	—	—	+	+	+	—	—	+	—	+	—
No. 99	—	—	+	—	+	+	+	+	—	—	—
No. 101	1	—	+	—	+	+	—	+	+	—	—
B. lactis aërogenes, No. 103	8	—	+	—	+	+	—	+	—	+	—
No. 106	2	+	+	—	+	—	—	—	+	—	—
B. coscoroba, No. 107	1	—	+	—	+	—	—	—	+	—	—

(In this and subsequent tables + = acid and gas, liquefaction of gelatin, motile, indol production, as the case may be; ⊥ = acid without gas; — = no acid or gas production, etc.)

Kligler emphasised the importance of salicin fermentation for differential purposes, and elaborated a comprehensive system of classification of dextrose-fermenting intestinal bacilli; he subdivided these organisms first according to their action on lactose, and the further classification depended mainly on the reactions in dulcite, saccharose and salicin; he included among the various sub-groups *B. proteus* and *B. cloacae* (gelatin liquefiers).

An older system of classification which is of interest to consider briefly is that of Jensen, who, on the basis of certain simple fermentative reactions, arbitrarily divided the whole coli-typhoid group into several main sub-groups; the criteria were the reactions in glucose, lactose, saccharose and maltose, and in this way the following organisms were differentiated: *B. faecalis alkaligenes*, *B.* "*metacoli*," *B. typhosus*, *B. paracolon*, *B. coli anaerogenes*, *B. coli* (two types) and *B.* "*pseudocoli*." This system was later amplified for the differentiation of coliform bacilli by Wulff, who employed certain additional tests—galactose, glycerin, adonite, mannite, dulcite and xylose fermentation.

This system of classification cannot be considered as sufficiently complete; thus no cognisance was taken of indol production and the fermentation of inosite. As will be shown later (*v.* p. 347), these reactions are important and characteristic features of certain *B. coli* sub-groups.

Houston, in connection with the bacteriological examination of water, has classified coliform bacilli into "typical" and "atypical" varieties (*v. supra*), and further divided the typical organisms according to the fermentation of dulcite and saccharose.

While different systems of classification have thus been adopted which in the hands of various workers have served a practical purpose in enabling them to recognise typical varieties as apart from those which are less characteristic, it can hardly be claimed that these organisms have yet been completely classified, nor that the significance of different characters has been accurately assessed.

General Outline of the Investigation.

In the observations to be recorded a further study has been made of the "*B. coli*" group, and the characters of a large number of strains of Gram-negative, aërobic, non-sporing, glucose-fermenting, non-liquefying bacilli (excluding the specific pathogenic organisms of this class) have been investigated.

The question of the biological classification of these organisms has also been studied from the serological aspect.

In addition certain observations have been made with regard to variations among the coliform bacilli and their biological significance.

The various strains were isolated from pathological specimens of urine, faeces, appendix, abscesses, etc.

Criteria Employed for Differentiation of Types.

In classifying coliform bacilli into particular types MacConkey's criteria were for the most part adopted, and for all practical purposes proved sufficiently complete. Raffinose and salicin fermentations were, however, found to yield further differentiation, and these tests were therefore included among the criteria adopted.

Certain other fermentable substances which have been employed by different workers proved of little or no differential value; thus maltose was found to be fermented by all the lactose-fermenting strains; glucose-fermenting, non-lactose-fermenting strains, however, vary in their action on this sugar. The same was found to be true for mannite. Laevulose and galactose were with few exceptions fermented by all the glucose-fermenting strains and glycerin by all the lactose-fermenters. Of course, as is well known, all lactose fermenters are also glucose fermenters. The behaviour of these bacilli in raffinose in the majority of cases corresponded to their effect on saccharose (as shown also by Winslow and Walker), but a certain proportion exhibited differences in their effects on these sugars.

The action of the lactose fermenters on dextrine differs from the fermentation produced in other carbohydrates; in the case of simple peptone water media containing dextrine and neutral red (as indicator), it was found that after twenty-four hours' incubation the neutral red became of a bright yellow colour and there was some degree of gas production; the gas formed was analysed and found to consist mainly of hydrogen. The medium remained neutral. This effect was common to all the lactose-fermenting types and the test afforded no information as regards differentiation of various strains.

With one exception all the strains that fermented inosite also fermented adonite. In all cases the Voges and Proskauer reaction was only given by inosite-fermenting strains.

It was found on repeated testing of various strains that the presence (or absence) of motility was a definite and constant character.

Similarly the presence (or absence) of indol in peptone water cultures (after ten days at 37° C.) proved to be a stable property of these organisms.

It was concluded therefore that of the various tests used by different workers, the most complete set of criteria for the differentiation of *B. coli* types were: (1) Presence or absence of motility; (2) production of indol; (3) the Voges and Proskauer reaction; the fermentation of (4) glucose, (5) lactose, (6) dulcite, (7) saccharose, (8) adonite, (9) inulin, (10) inosite, (11) raffinose, (12) salicin.

The majority of the strains to be described were re-tested after about two or three months, and apart from the variations noted (p. 360) their characters proved markedly stable.

Methods.

Motility.—In determining the presence or absence of this character a hanging-drop preparation from a 4 to 6 hours bouillon culture, or the "condensation" fluid of a sloped-agar culture of the same age, was examined. Tested in this way the presence (or absence) of motility proved to be a definite character.

Liquefaction of Gelatin.—This was tested for by making stab inoculations in ordinary nutrient gelatin and incubating the tubes at 22° C. for two weeks.

Indol Production.—The presence or absence of this property was determined by testing a ten-days peptone water culture of the strain in question with Ehrlich's reagents, paradimethylamidobenzaldehyde and persulphate of potassium, according to the usual procedure.

Voges and Proskauer Reaction.—For this test a 2 per cent. peptone water solution containing 1 per cent. glucose was inoculated and incubated at 37° C. for three days, when a solution of potassium hydrate was added and the tube allowed to stand at room temperature for several hours. A positive reaction was indicated by the development of a red fluorescence.

Fermentation Test.—The basis of the medium used for testing sugar fermentations was a 2 per cent. peptone solution with 0·5 per cent. sodium chloride. To avoid the possible decomposition of the sugar in the medium by overheating in the process of sterilisation, the different fermentable substances were added to the already sterilised medium in the form of sterile watery solutions. The proportion of sugar in the medium was 1 per cent.; neutral red (0·25 per cent. of a 1 per cent. watery solution) was added as an indicator of acid production. The medium was distributed in Durham's tubes (for the observation of gas production), and placed at 100° C. in the Koch's steriliser for ten minutes on two successive days. This short final sterilisation, while not acting deleteriously on the sugar, was sufficient to ensure complete sterility.

I have observed that for the proper appreciation of gas production fluid media must be used, as shake or stab cultures in solid agar media are open to fallacy. With certain specimens of peptone water agar (without meat extract), it was found that gas production might result on inoculation with *B. coli*, *i.e.* even in the absence of sugar, and this was especially marked if the agar was not freshly prepared.

Thus, a shake culture of *B. coli communis* made in peptone water agar immediately after preparation showed no gas production in the medium; the same medium a week later was again inoculated and on this occasion a considerable number of gas bubbles appeared in the medium after twenty-four hours' incubation; a fortnight later inoculation resulted in an abundant production of gas throughout the medium. No acid formation was, however, noted.

Litmus has been frequently used as an indicator of acid formation, but with this agent, especially when incorporated in nutrient medium, difficulties have frequently arisen owing to the many intermediate degrees of colour between unequivocal alkalinity on the one hand and undoubted acidity on the other. It has the further disadvantage, as I have noted, of being decolorised rapidly by many organisms of the *coli* group. In my own experience neutral red is a more valuable indicator as it is not subject to these disadvantages.

System of Classification and Designation Adopted.

Among the coliform bacilli studied, it seemed possible to classify into separate sub-groups, types of organisms having well-defined common characters.

Thus the different types which were characterised by the absence of gas production in the case of all the sugars fermented even after repeated subculture (*coli anaërogenes*) were classified in a separate sub-group. Serological investigations (*v. infra*) in which the group action of the complement-deviating antibody of immune sera to certain more typical *B. coli* varieties showed that the *coli anaërogenes* organisms were not closely related to the gas-producing types of *B. coli*.

It was also noted that certain types of coliform bacilli which produced on culture medium unusually large, thick, opaque, slimy and sometimes "viscid" colonies were all characterised by possessing the power of fermenting inosite while the usual *B. coli* varieties had not this property. These organisms were therefore grouped together and classified apart from the more typical coliform bacilli. All these varieties proved to be non-motile, all fermented lactose, saccharose, raffinose and salicin, and with one exception adonite; in this sub-group therefore several characters were definitely correlated. The separation of these organisms from the typical coliform bacilli was also found to be justified by serological tests as in the case of the *anaërogenes* sub-group.

It was further concluded from the serological studies referred to above, and dealt with in detail later, that a sub-group comprising all the "typical *B. coli*" could be recognised whose common characters were—gas-producing, indol-forming, non-inosite-fermenting.

After defining these three sub-groups, there still remained the organisms having the common characters—gas-producing, non-inosite-fermenting, non-indol-forming. Serological observations showed that this category did not represent a serologically homogeneous sub-group, but for purposes of a preliminary classification I have grouped all the organisms of the category together.

Thus four main sub-groups of the Gram-negative, glucose-fermenting, non-gelatin-liquefying intestinal bacilli may be recognised and this system of classification has been used in the following records. In addition, the

TABLE II.—*Sub-group A: Gas producing, indol forming, non-inosite fermenting, non-liquefying.*

Type.	Motility.	Glucose.	Lactose.	Dulcite.	Saccharose.	Adonite.	Inulin.	Raffinose.	Salicin.	Proskauer reaction.	Mannite	Maltose.	Faeces.	Urine.	Appendix abscesses	Other sources.	Total.
1. MacConkey, No. 71	+	+	+	+	+	—	—	+	+	—			10	15	3		28
2. *B. coli communis*	+	+	+	+	—	—	—	—	+	—			14	5	1	1 (Blood culture)	21
3. *B. vesiculosus*	—	+	+	—	—	—	—	—	—	—			4	5	4		13
4. *B. Grünthal*	+	+	+	—	—	—	—	—	+	—			4	6	2		12
5. *B. Schafferi*	—	+	+	+	—	—	—	—	+	—			4	6	1		11
6. *B. neapolitanus*	—	+	+	+	+	—	—	+	+	—			2	3		1 (Puerperal fever)	6
7. *B. Schafferi* type	—	+	+	+	—	—	—	—	—	—			1	3	2		6
8. MacConkey, No. 71 type	+	+	+	+	+	—	—	+	—	—			2	1	1	1 (Conjunctivitis)	5
9. MacConkey, No. 106	+	+	+	—	+	—	—	+	+	—			1	4			5
10. Neapolitanus type	—	+	+	+	+	—	—	+	—	—			1	2	1		4
11. MacConkey, No. 1	+	+	+	—	—	+	—	—	+	—			4				4
12.	—	+	—	+	—	—	—	—	—	—	+	+	4				4
13. *B. coscoroba*	—	+	+	—	+	—	—	+	+	—			2		1		3
14. *B. vesiculosus* type	—	+	+	—	—	—	—	—	+	—				2	1		3
15.	+	+	+	+	+	+	—	+	+	—			1	1		1 (Otitis)	3
16. *B. coli communis* type	+	+	+	+	—	—	—	+	+	—			1	2			3
17. *B. coli communis* type	+	+	+	+	—	—	—	—	—	—			1	2			3
18. *B. Schafferi* type	—	+	+	+	—	—	—	+	—	—			1	1			2
19.	—	+	—	+	+	—	—	+	—	—	+	+	1	1			2
20. *B. MacConkey*, No. 106 type	+	+	+	—	+	—	—	—	+	—			1	1			2
21. Neapolitanus type	—	+	+	+	+	—	—	—	+	—			1	1			2
22. MacConkey, No. 71 type	+	+	+	+	+	—	—	—	+	—						1 (Conjunctivitis)	1
23. *B. vesiculosus* type	—	+	+	—	—	—	—	+	—	—			1				1
24. *B. coli communis* type	+	+	+	+	—	—	—	+	—	—			1				1
25. *B. Grünthal* type	+	+	+	—	—	—	—	+	+	—				1			1
26. *B. Grünthal* type	+	+	+	—	—	—	—	—	—	—			1				1
27. MacConkey, No. 1 type	+	+	+	—	—	+	—	—	—	—				1			1
28. *B. acidi lactici*	—	+	+	—	—	+	—	—	—	—			1				1
29.	+	+	—	+	—	—	—	—	—	—	+	+	1				1
30.	—	+	+	+	+	+	+	+	+	—			1				1
31. MacConkey, No. 33	+	+	+	+	—	+	—	—	+	—			1				1
32.	—	+	+	—	+	—	+	+	+	—					1		1
33.	—	+	+	—	+	+	—	+	—	—			1				1
34.	—	+	—	—	+	—	—	—	+	—	+	+		1			1
35.	—	+	—	+	+	—	—	—	+	—	+	+		1			1
36.	+	+	—	—	—	—	—			—	—	—		1			1
											Total		68	66	18	5	157

TABLE III.—*Sub-group B: Gas producing, non-indol forming, non-inosite fermenting, non-liquefying.*

Type.	Motility.	Glucose.	Lactose.	Dulcite.	Saccharose.	Adonite.	Inulin.	Raffinose.	Salicin.	Proskauer reaction.	Mannite.	Maltose.	Faeces	Urine.	Appendix abscesses.	Other sources.	Total
1. *B. MacConkey*, No. 74 . .	+	+	+	+	+	—	—	+	+	—			4	8		1 (Cholecystitis)	13
2.	—	+	+	+	+	—	—	+	+	—			2	4			6
3.	—	+	+	+	—	—	—	—	+	—			1	1			2
4. *B. MacConkey*, No. 8 . .	—	+	+	—	—	—	—	—	—	—			1		1		2
5. *B. MacConkey*, No. 8 . .	—	+	+	—	—	—	—	—	+	—			1	1			2
6.	+	+	+	—	+	—	—	+	+	—				1			1
7.	—	+	+	—	+	—	—	+	+	—				1			1
8.	—	+	+	+	—	—	—	—	—	—				1			1
9.	+	+	+	—	+	—	—	+	—	—				1			1
10.	—	+	+	+	+	+	—	+	+	—				1			1
11. *B. MacConkey*, No. 7 . .	+	+	+	—	—	—	—	—	—	—			1				1
101. *B. paracolon* type . .	+	+	—	—	—	—	—			—	+	+	2	4			6
102.	+	+	—	+	—	—	—	—	+	—	+	+	5				5
103. *B. paracolon* type . .	—	+	—	—	—	—	—			—	+	+	2	3			5
104.	+	+	—	—	+	—	—	+	+	—	+	+	2				2
105.	+	+	—	—	+	—	—	+	—	—	+	+	1				1
106.	—	+	—	—	+	—	—	+	—	—	+	+		1			1
107.	—	+	—	+	+	—	—	+	+	—	+	+		1			1
											Total .		22	28	1	1	52

TABLE IV.—*Sub-group C: Gas producing, inosite fermenting, non-liquefying.*

Type.	Motility.	Glucose.	Lactose.	Dulcite.	Saccharose.	Adonite.	Inulin.	Raffinose.	Salicin.	Proskauer reaction.	Indol.	Faeces	Urine.	Appendix abscesses.	Other sources.	Total
1. *B. MacConkey*, No. 67	—	+	+	+	+	+	—	+	+	+	—	3	2			5
2.	—	+	+	+	+	+	+	+	+	+	+	3				3
3.	—	+	+	+	+	+	+	+	+	—	+	3				3
4.	—	+	+	+	+	+	—	+	+	—	+	3				3
5. *B. lactis aërogenes*	—	+	+	—	+	+	—	+	+	+	—	2			1 (Skin ulcer)	3
6. *B. MacConkey*, No. 99	—	+	+	—	+	+	+	+	+	—	—	1	1			2
7.	—	+	+	—	+	+	+	+	+	+	+	1	1			2
8.	—	+	+	+	+	+	—	+	+	+	+	1		1		2
9. *B. MacConkey*, No. 101	—	+	+	—	+	+	—	+	+	—	+	1	1			2
10.	—	+	+	—	+	+	—	+	+	—	—	1				1
11. *B. MacConkey*, No. 75	—	+	+	+	+	—	—	+	+	+	—	1				1
										Total .		20	5	1	1	27

TABLE V.—*Sub-group D: Non-gas producing in all Sugars fermented, non-liquefying.*

Type.	Motility.	Glucose.	Lactose.	Dulcite.	Saccharose.	Adonite.	Inulin.	Inosite.	Raffinose.	Salicin.	Proskauer reaction.	Indol.	Mannite.	Maltose.	Faeces.	Urine.	Other sources.	Total.
1.	—	+	—	—	—	—	—	—			—	—	—	—		2	1 (Skin ulcer)	3
2.	—	+	+	+	—	—	—	—			—	+	+	+		1		1
3.	+	+	+	—	+	—	—	—			—	+	+	+	1			1
4.	—	+	+	—	+	—	—	—			—	+	+	+		1		1
5.	+	+	+	+	+	—	—	—			—	+	+	+		1		1
6.	—	+	+	+	+	—	—	—			—	—	+	+		1		1
7.	—	+	—	+	—	—	—	—	—		—	+	+	+		1		1
8.	—	+	—	—	+	+	—	—	—	+	—	—	+	+		1		1
														Total .	1	8	1	10

various types belonging to these sub-groups have been designated numerically (*i.e.* 1, 2, 3, 4, etc.) in order of their prevalence in the series investigated. In the *B.* category the lactose-fermenters (1 to 11) have been distinguished from the non-lactose-fermenters (101 to 107) by a different series of numbers. The latter class includes certain "paracolon" types which in the serological tests appeared to be differentiated from organisms fermenting lactose in primary culture.

Two hundred and forty-six strains from urine (pathological specimens), faeces and other sources have been carefully studied and classified in this way (Tables II, III, IV, V). In Table VI, for comparison, those strains which correspond to MacConkey's types are classified according to his system.

TABLE VI.

MacConkey's types.	Faeces.	Urine.	Appendix Abscesses.	Other Sources.	Total.
No. 1	4	1	—	—	5
No. 2. *B. acidi lactici*	1	—	—	—	1
No. 4. *B. Grünthal*	5	7	2	—	14
No. 5. *B. vesiculosus*	5	7	5	—	17
No. 7	1	—	—	—	1
No. 8	2	1	1	—	4
No. 33	1	—	—	—	1
No. 34. *B. coli communis*	17	9	1	1	28
No. 35. *B. Schafferi*	6	10	3	—	19
No. 67	3	2	—	—	5
No. 71	12	16	4	2	34
No. 72	4	6	1	1	12
No. 74	4	8	—	1	13
No. 75	1	—	—	—	1
No. 99	1	1	—	—	2
No. 101	1	1	—	—	2
No. 103. *B. lactis aërogenes*	2	—	—	1	3
No. 106	2	5	—	—	7
No. 107. *B. coscoroba*	2	—	1	—	3
				Total	172

Note.—Of 246 strains 172 corresponded to types described by MacConkey.

Types of Coliform Bacilli Found in Pyogenic Infection of the Urinary System.

As shown by MacConkey, certain coliform types tend to be more prevalent than others in human and animal faeces; thus the type designated by him No. 71 is of commonest occurrence. As is well known, Gram-negative bacilli are the most frequent causative agents in pyogenic infections

of the urinary tract, and are found either alone or associated with the pyogenic cocci. In order to ascertain what types were characteristic of these pathological conditions a number of coliform bacilli isolated from urinary cases were carefully investigated.

The specimens of urine were mainly from cases of cystitis and pyelitis. The samples were centrifugalised in sterile tubes, and from the sediment, plates of Endo-agar or MacConkey's bile-salt-neutral-red-lactose-agar were inoculated by successive strokes of the platinum loop. Separate colonies were thus obtained, and to ensure the purity of the ultimate culture investigated further successive strokes were generally made (from single colonies) on another plate, and the final culture made from a single colony on the second plate. In some cases agar slope cultures were made from single colonies on the primary plate; this culture was then replated and the final culture obtained by subinoculating a single colony.

One hundred and seven strains of coliform bacilli from 90 cases of urinary sepsis were examined. In the majority of instances pure cultures of individual types were isolated. It might be expected in dealing with a bacterial group such as *B. coli* that separate colonies similar in appearance might on examination prove to belong to different types. I have on several occasions selected two or three similar colonies at random from the same plate and found on examination that they represented the same cultural type. Not infrequently, however, mixed cultures are met with, but it is remarkable that in such instances one notices some difference in the colonies, *e.g.* difference in size, thickness, depth of colour on Endo or MacConkey's agar, or complete absence of pink coloration. Of course non-lactose-fermenters produce "pale" colonies on these differential media, but in primary culture the absence of red coloration is no proof that the organism is a non-lactose fermenter. The fact that mixed cultures of different coliform species may occur in urinary sepsis is of special and obvious interest as regards the preparation of autogenous vaccines.

As in the case of faecal strains there is a distinct tendency towards the prevalence of certain types in urinary conditions, and the commonest intestinal species are also the most frequent types met with in pathological urines.

Type 1, Sub-group A, corresponds to *B. MacConkey* No. 71 and is the commonest coliform species met with (*v.* Tables I, II, VI). It proved the most frequent type (15 strains) in urinary sepsis. The other prevalent varieties were types A2 (*B. coli communis*), A3 (*B. vesiculosus*), A4 (*B. Grünthal*) A5 (*B. Schafferi*), B1 (*B. MacConkey* No. 74).

Of the 107 strains—

66 belonged to the sub-group A.
28 belonged to the sub-group B.
5 belonged to the sub-group C.
8 belonged to the sub-group D.

Thus the majority are referable to the A sub-group, which comprises all the "typical" *B. coli* varieties. Strains of non-lactose-fermenters were also isolated, A19, A34, A35 and A36; those of types 19, 34 and 35, however, developed lactose-fermenting variants in lactose medium (*v.* Table XXIX).

Type A36 corresponded in cultural reactions to *B. Morgan* No. 1; it was isolated in pure culture from a case of pyelitis and cystitis.

In sub-group B, type 1 was of commonest occurrence, corresponding to MacConkey's type No. 74. The relative prevalence of other varieties is shown in Table III. Among the organisms of sub-group B certain non-lactose-fermenters are also represented, including 7 strains of "paracolon" types B101 and B103.

Patrick reported organisms of these types in cases of bacilluria occurring in the course of typhoid fever. They were present in such large numbers as to render the urine turbid. In primary culture they did not exhibit any gas production and therefore simulated *B. typhosus* in cultural reactions. I had the opportunity of examining his strains, and found them to be typical "paracolon" bacilli with the reactions shown (B101 and 103) and similar to strains I had isolated from cases of urinary sepsis.

Certain non-lactose-fermenters of the B sub-group were also noted which developed lactose-fermenting variants spontaneously in lactose media (B106 and 107) (*v.* Table XXIX).

Five inosite-fermenters (sub-group C) were isolated from urine, and 8 strains referable to sub-group D. Four of the latter were non-lactose-fermenters; 2 of these fermented only glucose, and, being non-motile, were therefore similar in cultural reactions to *B. dysenteriae*, Shiga. They were not, however, agglutinated by an anti-Shiga serum. One of these strains developed a lactose-fermenting variant. The characters of these strains are shown in Table V.

Among the Gram-negative bacilli found in these cases of urinary sepsis *B. proteus* (*Urobacillus liquefaciens septicus Krogius*) was not infrequently noted, usually associated with *B. coli* or pyogenic cocci; Gram-negative bacilli characterised by absence of carbohydrate fermentation have also been noted both in mixed and pure culture; 4 strains of this type were isolated; 2 were motile (corresponding to the typical *B. faecalis alkaligenes*) and 2 non-motile.

Types Isolated from Faeces, Appendix Abscesses and other Sources.

One hundred and eleven strains from specimens of faeces were analysed in the same way; these were derived partly from normal specimens and also specimens submitted for bacteriological examination, *e.g.* for detection of *B. typhosus*. Their grouping was as follows:

Sub-group A, 68.
Sub-group B, 22.
Sub-group C, 20.
Sub-group D, 1.

As in the case of the urinary strains most belonged to the sub-group A; only one *anaërogenes* type was noted (D3).

The majority of the strains classified in this series were isolated from plates made directly from faeces, but 4 of sub-group B and 10 of C were obtained from cultures in brilliant green peptone water employed for the enrichment of *B. typhosus* (Browning, Gilmour and Mackie). As indicated later it was found that types of B and C sub-groups were more resistant to brilliant green than the A types; hence the relatively large proportion of C types in the series.

Among these strains were 4 non-lactose-fermenters of the A12 type and 1 of the A29 type; these two varieties differ from one another in motility. One non-lactose-fermenter of the A19 type was also isolated. This strain, like the similar type found in urine, developed a lactose-fermenting variant (*v.* Table XXIX).

Five non-lactose-fermenters of the B102 type were isolated from faeces, but all of these developed lactose-fermenting mutants. The other non-lactose-fermenters noted were B101 (2 strains), B103 (2 strains), B104 (2 strains), and B105. Single strains of the B103 and B105 types developed lactose-fermenting variants (*v.* Table XXIX).

Twenty strains from appendix abscesses were also investigated; these were grouped as follows:

Sub-group A, 18, of which the A3 and A1 types were most prevalent.
(All were lactose-fermenters [*v.* Table II].)
Sub-group B, 1.
Sub-group C, 1.

A few strains from other sources were examined: 2 from cases of conjunctivitis both belonging to the A sub-group, 1 from a suppurative otitis (A15), 1 from a case of puerperal sepsis (A6), 2 from skin ulcers (C5 and D1), 1 from a case of cholecystitis (B1), 1 from blood-culture after an abdominal operation (A2).

The total number of strains examined from different sources could therefore be classified as follows:

Sub-group A, 157.
(A1 most prevalent type, 28 strains;
10 primarily non-lactose-fermenters.)
Sub-group B, 52
(B1 most prevalent, 13 strains;
21 primarily non-lactose fermenters.)
Sub-group C, 27.
(C1 most prevalent type, 5 strains.)
Sub-group D, 10.
(D1 most prevalent type, 3 strains.)

Considering the various strains collectively in these series which corre-

spond to types isolated and classified by MacConkey, the commonest is the No. 71 type (34 strains) (Table VI). Of the series isolated from urine this type was also the most prevalent, though among the faecal strains the *B. coli communis* was the commonest. Collectively, however, the most prevalent types in my series were *B. MacConkey* No. 71 and *B. coli communis*.

With comparatively few exceptions, the Gram-negative bacilli found in urinary sepsis, as shown, are normal inhabitants of the intestine, and this parallelism between the faecal and urinary types is a further confirmation of the generally accepted view that these infections are auto-infections from the bowel.

As indicated above, the A sub-group comprises the most frequently occurring types of coliform bacilli, the so-called typical varieties. This group also appears to embrace the largest number of different varieties or types (36). While organisms of the sub-groups B and C are less frequently met with in excremental material, they nevertheless represent characteristic faecal organisms. Organisms of the *anaërogenes* type are of comparatively rare occurrence, but, as shown, this type may be associated with certain cases of urinary sepsis.

The Serological Investigation of the *B. coli* Group.

The following serological studies were originally carried out with a view to throwing further light on the biological relationships of the various types of *B. coli* and its congeners. The agglutination and complement-deviation reactions of immune sera to certain of the commoner varieties were studied, and the results, apart from their bearing on this particular question, represent observations of considerable interest from the purely immunological standpoint.

Agglutination Reactions.

While in the case of *B. typhosus*, precise species specificity is characteristic of an agglutinating antiserum, among the coliform bacilli a much more restricted degree of specificity was observed—specificity for the individual strain.

An immune serum to a particular strain of *B. typhosus* will agglutinate most *B. typhosus* strains with little variation in degree; immune sera to certain *B. coli* types, on the other hand, have been found to exert little or no action on other strains identical as regards cultural reactions to that used for immunisation.

Several authors have drawn attention to the high degree of specificity of *B. coli* agglutinins (Van Everen, Pfaundler, Cany, Wolf, Amiradzibi), but the agglutination reactions of these organisms have not been accurately studied in correlation with their classification into different types *qua* cultural reactions ; thus Amiradzibi immunised guinea-pigs against five strains which

all possessed certain common characters—power of fermenting glucose, lactose, clotting milk and producing indol; he found that the strain used for immunisation was the only one agglutinated. These common characters are, however, as shown above, referable to a considerable variety of types or species. In the experiments to be recorded it is shown that among the commoner types of *B. coli* (A sub-group) even after these organisms have been classified and separated into different species by cultural tests, it is still impossible to demonstrate any species specificity of an agglutinating anti-serum, and that agglutinating sera are specific only for the individual homologous strain.

Antisera were obtained to certain strains which represented common coliform types, (1) Type A1 (*B. MacConkey* No. 71), (2) Type A4 (*B. Grünthal*), (3) Type A3 (*B. vesiculosus*), (4) Type A2 (*B. coli communis*), and a number of other strains corresponding in all their characters with these types were tested with the immune sera.

Immune Sera.—Rabbits were immunised against the particular organisms by repeated intravenous injection of increasing amounts of bacillary emulsions sterilised at a temperature of 65° C. for half an hour. For this purpose twenty-four hours agar slope cultures were emulsified in convenient quantities of 0·85 per cent. sodium chloride solution. The series of doses were as follows: $\frac{1}{10}$, $\frac{1}{5}$, $\frac{1}{2}$, 1 and 2 emulsified agar slope cultures, given at intervals of 7 to 10 days. Ten days after the last injection the sera were tested with the strains used for immunisation, and if found of suitable value, *i.e.* agglutinating in a dilution of 1 : 2000 or in higher dilutions, the animal was bled and the serum after separation stored in sealed tubes. In the original experiments sterility of the serum was ensured by heating at 57° C. for one hour on three successive days. In some cases it was noted that there was a marked depreciation of the agglutinating value of the serum by heating, due apparently to the varying thermostability of the agglutinin. To obviate this the measures adopted for bleeding and collecting the serum were carried out with the utmost precautions to exclude contamination, and the serum was heated at 57° C. for only half an hour on two successive days.

Method of Carrying out the Agglutination Tests.—A twenty-four hours agar slope culture was emulsified in 5 c.c. of 0·85 per cent. salt solution, and the emulsion allowed to stand in the incubator for about one hour to allow the larger clumps and fragments of agar to deposit. The supernatant fluid was then decanted and made up to 10 c.c. Varying dilutions of the antiserum were mixed with equal volumes (0·5 c.c.) of bacillary emulsion, and the mixtures placed in narrow tubes in which the agglutination could be observed by the naked eye. As a control 0·5 c.c. of the bacillary emulsion was mixed with an equal volume of salt solution and included in the test series; this eliminated any fallacy due to auto-agglutination. It is to be noted, however,

that auto-agglutination was rarely seen among these bacilli. The tubes were placed in the incubator for one and a half hours, and at the expiry of that period, at room temperature for half an hour; they were again replaced in the incubator for two hours, when readings were taken of the results. Ultimately they were allowed to stand at room temperature till next day, when further readings, if necessary, were made. It was usually noted that the variations in temperature produced in this way set up convection currents in the fluid and this hastened agglutination. The degree of agglutination was determined by the amount of sediment in the various tubes as compared with the control or by the clarity or turbidity of the supernatant fluid as compared with the fluid in the control tube.

Complete agglutination is signified in the tables by + + + +, and lesser degrees by + + +, + +, and +.

Results Observed with Antisera to A Types 1, 2, 3 and 4.—Marked specificity for the individual strain on the part of these immune sera was observed. Tables VII, VIII, IX and X show that the only strains agglutinated to any extent by the *corresponding* antiserum were the particular strains used for immunisation. Thus, the antiserum to strain 1 type 1 agglutinated strain 1 in dilutions up to 1 : 50,000; 14 other strains of the same type were tested with the antiserum but none showed any agglutination by dilutions higher than 1 : 500, and 8 were not even agglutinated by a dilution of 1 : 100. A strain of type 3 also exhibited little reaction with the type 1 antiserum (Table VII). Similar results were obtained with antisera to types 2, 3 and 4.

While this restricted specificity was found to be the general rule with antisera to these common types of *B. coli* an exception has been noted: an antiserum to a type 2 (*B. coli communis*) was found to agglutinate a particular strain of type 1 (*B. MacConkey* No. 71) in a four times higher dilution than in the case of the homologous strain (Table XI), and this type 1 strain was not found to be specially susceptible to other *B. coli* agglutinins (Tables IX and X), *i. e.* it was not itself susceptible to other agglutinating sera nor did it show any tendency to auto-agglutination. Moreover, this agglutinin had no effect on a number of other strains of type 1 (Table XI).

To ascertain whether this peculiarity was a function of the immune animal, another antiserum to the same type 2 strain was obtained and the serum behaved in practically the same manner, indicating that this property of "paragglutination" was dependent on the particular strain (Table XI).

It is noteworthy that this instance of paragglutination is characterised by the more powerful effect of the paragglutinin than the primary agglutinin.

As is well known, the agglutinin has marked affinities for the homologous bacillus, and is absorbed or used up by the organisms during the process of agglutination. Moreover, a bacillary emulsion is capable of absorbing much

TABLE VII.—*Antiserum to Strain* 1, B. coli, *Sub-group A, Type* 1 (B. MacConkey *No.* 71).

Dilution	1 : 100	1 : 500	1 : 1000	1 : 5000	1 : 10,000	1 : 20,000	1 : 30,000	1 : 50,000
Strain 1, A1	++++	++++	++++	++++	++++	++++	+++	+

Other strains having same characters, i. e. *of Type A*1.

Strains 4, 6, 7, 10, 11, 12, 13, 15	0	0	0	0	0	0	0	0
Strains 3, 9	++	+	0	0	0	0	0	0
Strains 2, 8	+	0	0	0	0	0	0	0
Strains 5, 14	+++	++	0	0	0	0	0	0
Strain 1, A3	++	0	0	0	0	0	0	0

Controls showed no agglutination.

TABLE VIII.—*Antiserum to Strain* 1, B. coli, *Type A*2 (B. coli communis).

Dilution	1 : 200	1 : 400	1 : 800	1 : 1600	1 : 3200	1 : 6400	1 : 8000	1 : 10,000
Strain 1, A2	++++	++++	++++	++++	++++	+++	++	+

Other strains having same characters, i. e. *of Type A*2.

Strains 2, 3, 4, 5, 6, 7, 8, 9, 10	0	0	0	0	0	0	0	0
Strain 11	+	0	0	0	0	0	0	0
Strain 1, A4	0	0	0	0	0	0	0	0

Controls showed no agglutination.

TABLE IX.—*Antiserum to Strain* 1, B. coli, *Type A3* (B. vesiculosus)

Dilution	1 : 60	1 : 120	1 : 240	1 : 480	1 : 960	1 : 2000
Strain 1, A3	++++	++++	++++	+++	+++	++

Other strains having same characters, i.e. *of Type A3.*

Strains 3, 4, 5, 6, 7	0	0	0	0	0	0
Strain 2	+	0	0	0	0	0
„ 8	++	+	0	0	0	0
„ 1, A1	+	0	0	0	0	0
„ 1, A4	+	0	0	0	0	0

Controls showed no agglutination.

TABLE X.—*Antiserum to Strain* 1, B. coli, *Type A4* (B. Grünthal).

Dilution	1 : 50	1 : 100	1 : 200	1 : 400	1 : 800	1 : 1600	1 : 3200	1 : 8000	1 : 10,000
Strain 1, A4	++++	++++	++++	++++	++++	++++	++++	+++	+

Other strains having same characters, i.e. *of Type A4.*

Strains 3, 4, 6, 8	0	0	0	0	0	0	0	0	0
„ 2, 5, 9	+	+	0	0	0	0	0	0	0
„ 7, 10	+	0	0	0	0	0	0	0	0
Strain 1, A1	+++	+	0	0	0	0	0	0	0
„ 1, A3	++	0	0	0	0	0	0	9	0

Controls showed no agglutination.

Table XI.—*First Antiserum to Strain* 1, B. coli, *Type A2* (B. coli communis).

Dilution	1 : 100	1 : 1000	1 : 8000	1 : 10,000	1 : 20,000	1 : 30,000	1 : 40,000
Strain 1, A2	++++	++++	++	+	0	0	0
„ 1, A1 (*B. MacConkey*, No. 71)	++++	+++	+++	+++	+++	+++	++

Ten other strains having same characters as Strain 1, A1 showed no agglutination with antiserum diluted 1 : 500.

Second Antiserum to Strain 1, *A2*.

Dilution	1 : 200	1 : 400	1 : 1000	1 : 2000	1 : 4000	1 : 8000	1 : 16,000
Strain 1, A2	++++	+++	+++	++	0	0	0
„ 1, A1	+++	+++	+++	+++	++	+	0

Controls showed no agglutination.

Table XII.—*Antiserum to Strain* 1, B. coli, *Type A1 absorbed at* 1 : 500 *by large Excess of Emulsion of*—

(1) Strain 1, A1 ;
(2) „ 2, A1 ;
(3) „ 1, A2.

Treated Sera.

Tested with Strain 1, A1 :

Dilution	1 : 600	1 : 1200	1 : 2400	1 : 4800	1 : 9600	1 : 12,000
(1)	++	+	0	0	0	0
(2)	++++	++++	++++	+++	+++	+
(3)	++++	++++	++++	+++	+++	+

Controls showed no agglutination.

Table XIII.—*Antiserum to Strain* 1, *A4* (B. Grünthal), *absorbed at* 1 : 1000 *by Excess of Emulsion of*—

(1) Strain 1, A4;
(2) „ 2, A4;
(3) „ 1, A3.

Treated Sera.

Tested with Strain 1, A4: Dilution	1 : 1000	1 : 2000	1 : 4000	1 : 8000	1 : 10,000
(1)	0	0	0	0	0
(2)	++++	++++	++++	++	0
(3)	++++	++++	++++	+	0

Controls showed no agglutination.

Table XIV.—(1) *Antiserum to Strain* 1, *A2* (B. coli communis) *absorbed by Strain* 1, *A1* (v. *Table* 11) *at* 1 : 1000 *dilution*; (2) *Same Antiserum absorbed by Strain* 1, *A2 at* 1 : 1000 *dilution.*

Treated Serum (1).

Dilution	1 : 1000	1 : 2000	1 : 3000	1 : 4000	1 : 6000	1 : 8000
Tested with:						
Strain 1, A2	++++	++++	++++	++++	+++	++
„ 1, A1	++	+	0	0	0	0

Treated Serum (2).

Tested with:						
Strain 1, A2	++	+	0	0	0	0
„ 1, A1	0	0	0	0	0	0

Controls showed no agglutination.

more agglutinin than is required for complete agglutination of the organisms. It was found that if these agglutinating sera were absorbed (1) by the homologous strain, (2) another strain of the same type, and (3) another strain of a different type, and then tested with the homologous strain, the agglutinin could be almost completely absorbed by the homologous strain, but that the absorptive effect of the other organisms was relatively weak and equal in degree (Tables XII and XIII).

For this purpose concentrated emulsions were prepared, and a certain dilution, 1 : 500 or 1 : 1000, of the antiserum was treated with the different organisms at 37° C. for two hours; the mixtures were centrifugalised till the supernatant fluids were quite clear; these were pipetted off and tested each with the homologous strain in various further dilutions.

Absorption tests were also carried out with the antiserum which showed the paragglutination phenomenon. It was found that while treatment of the serum by the strain used for immunisation removed the agglutinin both for this strain and the heterologous strain, the heterologous strain was only capable of absorbing its own agglutinin (Table XIV). This is true for coagglutination effects generally (Castellani), and showed that the two strains were not serologically identical.

It was thus quite impossible to establish any differentiation by agglutination tests between different types of these coliform bacilli, and no species specificity was displayed by their agglutinins; the specificity is restricted to the individual strain, and, by the ordinary agglutination reaction, and also by absorption tests, it is quite impossible to demonstrate that organisms of the same species (determined by cultural reactions) as the homologous strain, are more closely related to it than representatives of other types. Thus the individuality of the bacterial strain is most strikingly elicited. In this group strains are constantly assuming new characters (*v.* p. 360) and becoming highly specialised. *Hence we must assume that a high degree of individuality is attained by each strain and that differences of cultural characters within certain limits are of little significance.*

Results observed with antisera to B. types 1 *and* 2.—In the foregoing observations regarding the action of *B. coli* agglutinins, the commoner types, *B. MacConkey* No. 71, *B. coli communis*, *B. Grünthal*, *B. vesiculosus* belonging to the indol forming sub-group (A) of coliform bacilli were studied; further experiments were then carried out with agglutinating sera to certain of the B sub-group which are of less frequent occurrence.

Antisera were obtained to strains of types B1 (*B. MacConkey* No. 74) and B2 whose characters are shown in Table III. A number of other strains identical in their characters to these types were tested with the respective immune sera. The results with an antiserum to strain 1, type B1 are shown in Table XV. It was noted that while the strain used for immunisation was agglutinated by a 1 : 8000 dilution of the serum, three

other identical strains were only agglutinated by a lower dilution (1 : 100, 1 : 1000), and strains of sub-group A type 1 and B2 also were not agglutinated except by low dilutions. Strains 3 and 6 were agglutinated, however, to the same degree as the strain used for immunisation.

An antiserum to strain 3 was also obtained and tested with the other strains (including No. 1). The corresponding effect was found to occur, *i.e.* marked agglutination of strain 3 and also of strains 1 and 6, while the other strains were not affected to any marked extent (Table XVI). In this type therefore the specificity was not so restricted, and the homologous strain was not the only strain which showed marked agglutinability by the antiserum. Other strains of the same type were, however, not more agglutinable than a heterologous strain belonging to an entirely different sub-group. Thus no species differentiation could be elicited by means of these antisera.

In the case of the antiserum to a strain of B2, two other corresponding strains were also tested. The strain used for immunisation was agglutinated by dilutions up to 1 : 10,000 (Table XVII); strain 2 was agglutinated by dilutions up to 1 : 3200, but strain 3 showed a less degree of agglutinability (end-titre 1 : 800).

Among these B types there is a relative specificity of the agglutinin for the individual strain as in the case of the indol-forming types, but the results indicate that the specificity is much less restricted. In the case of agglutinating sera to A types 1, 2, 3 and 4, the strain used for immunisation showed marked agglutination, while other strains of the same types respectively were practically inagglutinable except by low dilutions of the serum. In the case of antisera to type B1 strains, other strains of the same type showed an almost equal agglutinability, and as regards the antiserum to strain 1, B2, of the two other corresponding strains, one was agglutinated by relatively high dilutions though not quite equal in agglutinability to the strain used for immunisation.

Results observed with antisera to B types 101 *and* 103 (*paracolon bacilli*).—Agglutinating sera for two types of the so-called paracolon bacilli, *i.e.* types which ferment glucose and mannite with gas production and do not ferment lactose or saccharose. In this case specificity for the individual strain was completely absent and exact species specificity was observed.

The immune serum to strain 1, B101, agglutinated this strain in dilutions as high as 1 in 8,000,000 (an unusually powerful agglutinin), and three other similar strains were agglutinated by equally high dilutions (Table XVIII).

It is of interest to note that strain 4, B101, underwent spontaneous variation in saccharose medium (fluid); so that a new strain was developed differing from the original strain in fermenting saccharose within twenty-four hours' growth (*v.* Table XXIX). Both the original and variant strain were equally agglutinable by the antiserum. The immune serum to strain 1,

B103, agglutinated three other similar strains to the same degree as the strain used for immunisation (Table XIX).

Thus among the coliform bacilli investigated serologically, different grades of specificity on the part of agglutinating sera have been noted.

(1) In the case of the commoner types, sub-group A, types 1, 2, 3 and 4 (gas producing, indol +, inosite —, lactose +), marked specificity for the individual strain was observed.

(2) In the case of certain less common types, sub-group B, types 1 and 2 (gas producing, indol —, inosite —, lactose +), absolute specificity for individual strains was not observed, but there was not complete specificity for the species or type as determined by cultural tests.

(3) In the case of certain paracolon types (B101 and 103) (gas producing, indol —, inosite —, lactose —) precise specificity for the cultural type was observed.

Complement Deviation Reactions.

As in the case of agglutination by immune sera to organisms of the A sub-group the specificity of the complement-deviating immune body is found to be related, not to the homologous species, but to the strain used for immunisation. This specificity for the individual strain was not so pronounced as in the case of the agglutinin and was only relative. While "group" agglutination among the different *B. coli* species was slight and often inappreciable, the complement-deviating antibody displayed marked "group" action within certain well-defined limits, and in the experiments to be recorded some indication of the biological relationships of different *B. coli* types has been elicited from a study of these group reactions.

Complement Deviation Methods.

Antigen: Emulsions of the bacilli in 0·85 per cent. salt solution were generally used as antigen; these were prepared by mixing an eighteen to twenty-four hours agar slope culture of the particular organism with a given quantity (10 c.c.) of salt solution. The whole agar surface had been inoculated abundantly so that a continuous growth was obtained, and by using tubes with agar surfaces of approximately equal size, the emulsions of different organisms generally exhibited an approximately equal degree of turbidity.* The emulsions were sterilised in a vaccine bath at 65° C. for half an hour; this is usually sufficient to ensure the killing of organisms of the *coli* group, and does not affect the antigenic value of the emulsions. These antigens generally exhibited a more or less degree of anti-comple-

* Table XX shows how closely the antigenic properties of these emulsions correspond; compare the deviation by the A4 antiserum + strains 2 A4, 1 A3 and 1 A1.

Table XV.—*Antiserum to Strain* 1, B. Coli, *Type B*1 (B. MacConkey, *No.* 74).

Dilution	1:100	1:500	1:1000	1:2000	1:4000	1:6000	1:8000	1:10,000
Strain 1, B1	++++	++++	++++	++++	++++	+++	++	0
„ 2, B1	++++	+++	++	0	0	0	0	0
„ 3, B1	++++	++++	++++	++++	++++	+++	++	0
„ 4, B1	++	0	0	0	0	0	0	0
„ 5, B1	++++	0	0	0	0	0	0	0
„ 6, B1	++++	++++	++++	++++	++++	+++	+	0
„ 1, A1	+++	++	0	0	0	0	0	0
„ 1, B2	+++	+	0	0	0	0	0	0

Controls showed no agglutination.

Table XVI.—*Antiserum to Strain* 3, B. coli, *Type B*1.

Dilution	1:50	1:100	1:800	1:1600	1:3200	1:6400
Strain 1, B1	++++	++++	++++	++++	+++	+
„ 2, B1	++++	+++	0	0	0	0
„ 3, B1	++++	++++	++++	++++	++	0
„ 4, B1	++++	+++	+	0	0	0
„ 5, B1	++	0	0	0	0	0
„ 6, B1	++++	++++	++++	+++	++	+
„ 1, A1	+++	+	0	0	0	0

Controls showed no agglutination.

TABLE XVII.—*Antiserum to Strain* 1, B. coli, *Type B2*.

Dilution	1 : 50	1 : 100	1 : 400	1 : 800	1 : 1600	1 : 3200	1 : 6400	1 : 10,000
Strain 1, B2	++++	++++	++++	++++	++++	++++	+++	+
,, 2, B2	++++	++++	++++	++++	+++	++	0	0
,, 3, B2	++++	++++	+++	++	0	0	0	0
,, 1, A1	+++	0	0	0	0	0	0	0

Controls showed no agglutination.

TABLE XVIII.—*Antiserum to Strain* 1, *B*101 (B. paracolon *type*).

Dilution	1 : 1,000,000	1 : 2,000,000	1 : 4,000,000	1 : 6,000,000	1 : 8,000,000	1 : 10,000,000
Strain 1, B101	++++	+++	++	++	+	0
,, 2, B101	++++	++++	++++	+++	++	0
,, 3, B101	++++	++++	++++	+++	++	0
,, 4, B101	++++	++++	++++	+++	++	0
,, 1, A1	0	0	0	0	0	0
,, 1, B1	0	0	0	0	0	0
,, 1, B103	+++	0	0	0	0	0

Note the very high degree of potency attained by this particular agglutinating serum.

TABLE XIX.—*Antiserum to Strain* 1, *B*103 (B. paracolon *type*).

Dilution	1 : 500	1 : 1000	1 : 2000	1 : 4000	1 : 8000	1 : 16,000	1 : 32,000
Strain 1, B103	++++	++++	++++	++++	+++	+++	+
,, 2, B103	++++	++++	++++	++++	+++	+++	+
,, 3, B103	++++	++++	++++	++++	+++	++	+
,, 4, B103	++++	++++	++++	++++	+++	++	++
,, 2, B101	++	0	0	0	0	0	0

Controls showed no agglutination.

mentary action by themselves; this effect appeared to depend mainly on two factors—(1) the particular specimen of complement, and (2) the presence in the emulsion of fragments of agar, which, after heating of the emulsion, render it extremely viscous. It was generally found better to employ complement-serum eighteen to twenty-four hours after its withdrawal as fresh complement tends to be more deviable by anti-complementary agents.*

TABLE XX.—*Lysis of 0·5 c.c. 5 per cent. Ox Blood + 5 Doses Immune Body.*

Antiserum to Strain 1, A4 (*B. Grünthal*).	Bacillary emulsion.	Doses of complement.					Complement deviated by emulsion alone.	
		2 D.	5 D.	10 D.	15 D.	20 D.	2 D.	5 D.
0·025 c.c.	0·4 c.c. Strain 1, A4	0	0	0	0	0	Trace	Just c.
0·01 „		0	0	0	0	0	—	—
0·005 „		0	0	0	0	0	—	—
0·001 „		0	0	0	0	Com.	—	—
0·0005 „		0	0	Al. com.	Com.	—	—	—
0·0001 „		0	Dist.	Com.	—	—	—	—
0·025 „	0·4 c.c. Strain 2, A4	0	0	0	0	0	Just c.	Com.
0·01 „		Dist.	Mkd.	Al. com.	Com.	—	—	—
0·05 „		Mkd.	Al. com.	Com	—	—	—	—
0·001 „		Al. com.	Com.	—	—	—	—	—
0·025 „	0·4 c.c. Strain 1, A3	0	0	0	0	0	V. mkd.	Com.
0·01 „		Dist.	Dist.	Mkd.	Com.	—	—	—
0·005 „		Dist.	Mkd.	Com.	—	—	—	—
0·001 „		Mkd.	Just c.	—	—	—	—	—
0·025 „	0·4 c.c. Strain 1, A1	0	0	0	0	0	Mkd.	Al. c.
0·01 „		0	Dist. trace	V. mkd.	Com.	—	—	—
0·005 „		0	Dist. trace	Al. com.	—	—	—	—
0·001 „		Trace	Mkd.	Com.	—	—	—	—

0·025 c.c. antiserum alcne deviated 2 D. of complement.
0·01 „ „ „ „ no complement.

In this and in subsequent tables: C. or Com. = complete lysis. Al. c. or Al. Com. = almost complete lysis. V. mk. or V. mkd. = very marked lysis. Mk. or Mkd = marked lysis. Dt. or Dist. = distinct lysis. Tr. or Trace = trace of lysis F. Trace = faint trace. 0 = no lysis.

Apart from this, individual animals yield complements which may display varying degrees of deviability; some are extremely deviable, while others are little affected by the usual inhibitory agents, and it is thus impossible to predicate how a certain specimen of complement-serum will behave. As regards the other complicating factor, it was found essential before heating to centrifugalise the emulsions for one or two minutes. This deposited any agar fragments and the supernatant emulsion was then pipetted off.

* This is well known as regards the Wassermann reaction.

It was thus possible to obtain bacillary emulsions which, with suitable complements, showed little anti-complementary effect in the quantities used.

Bacillary extracts have been extensively used in place of simple emulsions. These were originally employed by Wassermann and Bruck, and various workers have preferred them on the ground that they are less anti-complementary than emulsions. I have prepared extracts by Dean's method of alternately freezing and thawing emulsions and then removing the bacteria by centrifugalisation. These extracts were found no less inhibitory in certain amounts with various specimens of complement than the ordinary emulsions. Throughout the experiments emulsions have been used as antigen; they are easily prepared, and with suitable complements exhibit little inhibitory effect.

TABLE XXI.—*Lysis of 0·5 c.c. 5 per cent. Suspension Ox Blood + 5 Doses Immune Body.*

Antiserum to Strain 1, A1 (*B. No. 71 McC.*).	Bacillary emulsion 0·4 c.c.	Doses of complement.					Complement deviated by emulsion alone.	
		2 D.	4 D.	7 D.	12 D.	20 D.	2 D.	4 D.
0·01 c.c.	Strain 1, A1 (B. No. 71)	0	0	0	0	0	—	—
0·005 „		0	0	0	0	0	—	—
0·001 „		0	0	0	0	0	Mkd.	Just c.
0·0005 „		0	0	0	0	0	—	—
0·0001 „		0	Dist.	Just c.	—	—	—	—
0·01 „	Strain 2, A1	0	0	0	0	0	—	—
0·005 „		0	0	0	Trace	Com.	Mkd.	Just c.
0·001 „		0	Dist.	Mkd.	Al. com.	Com.	—	—
0·01 „	Strain 1, A6 (*B. neapolitanus*)	0	0	0	0	Trace	—	—
0·005 „		0	0	0	Trace	V. mkd.	V. mkd.	Just c.
0·001 „		0	Mkd.	Mkd.	V. mkd.	Com.	—	—
0·01 „	Strain 1, A2 (*B. coli communis*)	0	0	0	0	Trace	—	—
0·005 „		0	0	0	Trace	Mkd.	Mkd.	Just c.
0·001 „		0	Trace	Mkd.	V. mkd.	Com.	—	—
0·01 „	Strain 1, A4 (*B. Gränthal*)	0	0	Dist.	Mkd.	Al. com.	Com.	Com.
0·005 „		0	Dist.	Mkd.	V. mkd.	Al. com.	—	—
0·001 „		Dist.	V. mkd.	Al. com.	Com.	Com.	—	—

0·025 c.c. antiserum alone deviated 2 D. of complement.
0·01 „ „ „ „ no complement.

The *immune sera* used were those already referred to in connection with the agglutination experiments.

Guinea pig's serum was used as *complement*, and ox-blood corpuscles sensitised with five doses of a haemolytic immune body (from the rabbit) was employed as the *haemolytic system*.

The method of carrying out the tests, where careful comparisons were made of the deviation of an antiserum along with different bacillary strains, was as follows: varying quantities of the serum were added to a fixed quantity of the antigen, and then a quantitative estimation of the amount of complement deviated by these mixtures was made by adding varying amounts of complement from 3 M.H.D up to 20 M.H.D. (for 0·5 c.c. of the test blood suspension), incubating the mixtures for $1\frac{1}{4}$ hours at 37° C., and then

TABLE XXII.—*Lysis of 0·5 c.c. 5 per cent. Suspension Ox Blood + 5 Doses Immune Body.*

Antiserum to Strain 1, A3 (*B. vesiculosus*).	Bacillary emulsion 0·4 c.c.	Doses of complement.					Complement deviated by emulsion alone.		
		2 D.	5 D.	10 D.	15 D.	20 D.	2 D.	5 D.	7 D.
0·025 c.c.	Strain 1, A3 (*B. vesiculosus*)	0	0	0	0	0	—	—	—
0·01 ,,		0	0	0	0	0	—	—	—
0·005 ,,		0	0	0	0	0	V. mk.	Al. com.	Com.
0·001 ,,		0	0	0	0	0	—	—	—
0·0005 ,,		0	0	Mkd.	Al. com.	Com.	—	—	—
0·0001 ,,		Dist.	Mkd.	Com.	—	—	—	—	—
0·025 ,,	Strain 2, A3	0	0	0	0	Dist.	—	—	—
0·01 ,,		0	0	Dist.	V. mkd.	Com.	Dist.	Al. com.	Com.
0·005 ,,		0	Trace	Mkd.	Com.	Com.	—	—	—
0·001 ,,		Trace	Mkd.	Com.	Com.	Com.	—	—	—
0·025 ,,	Strain 1, A4 (*B. Grünthal*)	0	0	0	F. tr.	Dist.	—	—	—
0·01 ,,		0	0	Dist.	Al. com.	Com	Dist.	Al. com.	Com.
0·005 ,,		0	Trace	V. mkd.	Com.	Com.	—	—	—
0·001 ,,		Trace	Dist.	Com.	Com.	Com.	—	—	—
0·025 ,,	Strain 1, A9 (B. No. 106 *McConkey*)	0	0	0	F. tr.	Mkd.	—	—	—
0·01 ,,		0	0	Trace	V. mkd.	Com.	Dist.	Al. com.	Com.
0·005 ,,		0	0	Dist.	Com.	Com.	—	—	—
0·001 ,,		Trace	Dist.	Com.	Com.	Com.	—	—	—

0·025 c.c. antiserum alone deviated 1 D. of complement.
0·01 ,, ,, ,, ,, no complement.

adding 0·5 c.c. of the blood suspension. After a further hour's incubation the results were read.

Control tests were also carried out to determine the number of doses of complement absorbed by the antigen and immune serum respectively. At the same time the dose of complement after incubation for $1\frac{1}{2}$ hours was ascertained by adding suitable amounts of the complement-serum to tubes containing a volume of salt solution equal to that of the antigen used in the tests, incubating along with the other tubes and then adding the test corpuscles.

The number of doses of complement deviated was taken as one less than

that represented by the smallest amount in the series which produced complete lysis (complete lysis occurring when one dose is left free). The number of doses deviated by the serum and emulsion separately was deducted from the number of doses absorbed by the serum and antigen in combination, and the result represented the exact degree of deviation produced apart from the inhibitory effects of serum and bacillary emulsion. Thus any inequality in the anti-complementary action of different antigens was allowed for.

By this method, in which the amount of complement deviated by varying amounts of antiserum along with a fixed quantity of bacillary antigen is

TABLE XXIII.—*Lysis of* 0·5 *c.c.* 5 *per cent. Suspension Ox Blood* + 5 *Doses Immune Body.*

Bacillary emulsion.	Antiserum to Strain 1, A1 (*B. No.* 71 *McC.*).	Doses of complement.					Complement deviated by emulsion alone.	
	0·025 c.c.	2 D.	4 D.	7 D.	12 D.	20 D.	2 D.	4 D.
Strain 1, A1								
0·2 c.c.	—	0	0	0	0	F. tr.	Com.	Com.
0·12 ,,	—	0	0	F. tr.	F. tr.	Dist.	Com.	Com.
0·04 ,,	—	0	Trace	Dist.	Dist.	Mkd.	Com.	Com.
0·02 ,,	—	0	Dist.	Mkd.	Mkd.	Com.	Com.	Com.
Strain 1, A2								
0·2 c.c.	—	0	0	0	0	0	Com.	Com.
0·12 ,,	—	0	0	0	Trace	V. mkd.	Com.	Com.
0·04 ,,	—	0	F. tr.	Mkd.	Com.	Com.	Com.	Com.
0·02 ,,	—	Trace	Dist.	V. mkd.	Com.	Com.	Com.	Com.
Strain 2, A1								
0·2 c.c.	—	0	0	0	0	0	Com.	Com.
0·12 ,,	—	0	0	0	Mkd.	Mkd.	Com.	Com.
0·04 ,,	—	0	F. tr.	Trace	Mkd.	Com.	Com.	Com.
0·02 ,,	—	0	Trace	Al. com.	Com.	Com.	Com.	Com.

0·025 c.c. antiserum alone deviated 1 D. of complement.

tested, it is possible to precisely differentiate *B. typhosus* from *B. paratyphosus* A and B. In one of my own experiments 0·0002 c.c. of an anti-typhoid serum along with a strain of *B. typhosus* (not that used for immunisation) deviated over seventeen doses of complement, while with *B. paratyphosus* A 0·025 c.c. of the serum was required to produce a deviation of ten doses and 0·0002 c.c. produced practically no deviation. Thus by careful quantitative comparisons it is possible to establish a precise species differentiation between certain allied organisms. In the case of *B. typhosus* the relative specificity is for the species.

Results observed with antisera to A types 4, 1 *and* 3.—In the case of the antiserum to strain 1, A4 (*B. Grünthal*), over fifteen doses of complement were absorbed by the combination of 0·001 c.c. of antiserum and the strain

used for immunisation, while with another strain of the same type (No. 2) it was necessary to employ 0·025 c.c. of antiserum to obtain this degree of complement absorption, and on diminishing the amount of antiserum there was a rapid falling off in the amount of complement deviated (Table XX). With representatives of other typical *B. coli* varieties, the amounts of complement deviated by different quantities of antiserum were practically the same as those deviated with the No. 2 strain of type B4. Thus even by varying the amount of antiserum no demarcation could be demonstrated in the A sub-group between, for example, types 1 and 3 on the one hand and type 4 on the other. This was found to be true also in the case of antisera to types 1 and 3 of sub-group A (Tables XXI and XXII).

Experiments were also carried out in which the amount of antiserum was maintained constant and the quantity of antigen varied; with the antiserum to strain 1 of type 1 no differentiation could be established between another type 1 strain and a strain of a different type (type 2) (Table XXIII).

Group Reactions.

The group reaction was then studied to ascertain its significance as regards the biological relationships between different types and the classification or grouping of these organisms.

Group action by complement deviating sera has been studied in other bacterial classes; thus Sacquépée found that the food-poisoning group could be classified into two sub-groups (Enteritis I and II). An immune serum to an organism of sub-group I reacted with other sub-group I types but not with organisms of sub-group II; similarly an antiserum to a sub-group II type reacted only with other organisms of the same sub-group.

On testing the antiserum to strain 1 type 4 (*B. Grünthal*) along with a large number of different coliform strains (typical and atypical) it was found that the group reaction was iimited to a certain class. If these coliform bacilli are divided up as follows, as in the original classification given above (p. 323):

Coliform bacilli.

- Gas producing ("*aërogenes*") types.
  - Non-inosite fermenters.
    - Indol forming. *Sub-group A.*
    - Non-indol forming. *Sub-group B.*
  - Inosite fermenters. *Sub-group C.*
- Those that do not produce gas from any of the sugars fermented ("*anaërogenes*") types. *Sub-group D.*

then sub-group A will comprise all the typical varieties, *e.g. B. MacConkey*

TABLE XXIV.—*Lysis of 0·5 c.c. 5 per cent. Suspension Ox Blood + 5 Doses Immune Body.*

ANTISERUM TO STRAIN 1, A4 (B. GRÜNTHAL), 0·025 c.c.

Different strains of type	1	1	2	1	1	2	2	3	4	3	5	4	5	6	7	6	30	11	10	2	3	9	101	34	19	19	15	12		22	9	1	
Bacillary emulsion 0·4 c.c. — Sub-group	A	C	C	D	B	B	A	B	B	A	B	A	A	A	A	B	A	A	B	D	C	B	B	A	A	A	A	A		A	A	A	
				Coli anaërogenes																*Coli anaërogenes*			Paracolon						*B. para-typhosus B.*	Conjunctiva			*B. proteus*
Doses of complement 3D	O	J.C.	V. mk.	Al. C.	Mk.	O	O	Al. C.	Dt.	O	J.C.	O	O	O	O	O	O	O	Al. C.	O	C	C	C	O	O	O	O	O	C	Mk.	Tr.	C	C
5D	O	C	C	C	Al.C.	Mk.	O	C	Mk.	O	C	O	O	O	O	Tr.	O	O	C	Tr.	C	C	C	O	O	O	O	O	C	Al.C.	Dt.	C	C
10D	O	C	C	C	C	C	O	C	C	O	C	O	O	O	O	Mk.	O	O	C	C	C	C	C	O	O	O	O	O	C	C	Al.C.	C	C
15D	O	C	C	C	C	C	O	C	C	O	C	O	O	O	O	C	O	O	C	C	C	C	C	O	O	O	O	O	C	C	C	C	C
20D	O	C	C	C	C	C	Tr.	C	C	Tr.	C	O	Tr.	O	O	C	Tr.	Tr.	C	C	C	C	C	O	O	O	O	O	C	C	C	C	C
ANTISERUM TO STRAIN 1, A3 (B. VESICULOSUS), 0·025 c.c.																																	
Doses of complement 3D		Dt.	V. mk.	Dt.	Dt.			Tr.		O	J.C.	O	O	O	O	O												Tr.	C	Mk.	Tr.	C	
5D		Al.C.	C	V. mk.	V. mk.			Dt.		O	J.C.	O	O	O	O	Tr.												Tr.	C	C	Dt.	C	
10D		C	C	C	C			C		O	J.C.	O	O	O	O	Mk.												Tr.	C	C	Al.C.	C	
15D		C	C	C	C			C		O	J.C.	O	Tr.	O	O	C												Mk.	C	C	C	C	
20D		C	C	C	C			C		Tr.	J.C.	Mk.	Dt.	F. tr.	O	C												V. mk.	C	C	C	C	
Complement deviated by emulsion alone	8D	2D	3D	2D	4D	5D	4D	5D	4D	3D	2D	4D	5D	4D 6D	3D	7D	3D	4D	4D	6D	2D	2D	2D	4D	4D	6D	4D	4D	3D	4D	4D	3D	4D

No. 71, *B. coli communis*, etc. It was found that the group effect with the A4 antiserum was limited to these types, *i.e.* to sub-group A; for example with representatives of this sub-group over fifteen doses of complement were

TABLE XXV.

Antiserum to strain 1, A4 (*B. Grünthal*).	Bacillary emulsion.	Doses of complement.					Complement deviated by emulsion alone.		
		2 D.	5 D.	10 D.	15 D.	20 D.	2 D.	5 D.	7 D.
0·025 c.c.	0·4 c.c. Strain 2, A4, lactose +, indol +	0	0	0	0	0	Mkd.	Com.	—
0·01 „		0	0	Trace	Dist.	Al. com.	—	—	—
0·005 „		0	0	V. mkd.	Com.	—	—	—	—
0·001 „		Trace	Dist.	Al. Com.	—	—	—	—	—
0·025 „	0·4 c.c. Strain A12, lactose —, adonite —, inosite —, indol +	0	0	0	0	0	Mkd.	Com.	—
0·01 „		0	0	0	Dist.	V. mkd.	—	—	—
0·005 „		0	Trace	Al. com.	Com.	—	—	—	—
0·001 „		Trace	Dist.	Al. com.	—	—	—	—	—
0·025 „	0·4 c.c. Strain A19, lactose + after mutation, adonite —, inosite —, indol +	0	0	0	0	0	—	Mkd.	Com.
0·01 „		0	0	0	Trace	Mkd.	—	—	—
0·005 „		0	0	Dist.	Mkd.	Com.	—	—	—
0·001 „		0	Dist.	V. mkd.	Com.	—	—	—	—
0·025 „	0·4 c.c. Strain A15, lactose +, adonite +, inosite —, indol +	0	0	0	0	0	Mkd.	Com.	—
0·01 „		0	0	0	0	Trace	—	—	—
0·005 „		0	0	Dist.	Com.	—	—	—	—
0·001 „		0	Trace	Com.	—	—	—	—	—
0·025 „	0·4 c.c. Strain A34, lactose —, indol +, inosite —	0	0	0	0	0	Mkd.	Com.	—
0·01 „		0	0	0	Trace	Com.	—	—	—
0·005 „		0	Dist.	V. mkd.	Al. com.	Com.	—	—	—
0·001 „		Trace	Dist.	Com.	Com.	Com.	—	—	—
0·025 „	0·4 c.c. Strain A6, lactose +, indol +, inosite —	0	0	0	0	0	—	—	—
0·01 „		0	0	0	0	0	Dist.	Al. com.	Com.
0·005 „		0	0	Trace	Al. com.	Com.	—	—	—
0·001 „		0	Dist.	Com.	Com.	Com.	—	—	—

deviated in the presence of 0·025 c.c. of the antiserum, while with representatives of the other sub-groups B, C and D, in the presence of the same amount of antiserum, not more than five doses were deviated, and with some no deviation was observed (Table XXIV). Some of the strains were tested both with the A4 antiserum and also with the A3 antiserum and the results

were found to correspond (Table XXIV). It is noteworthy that certain representatives of sub-group A whose fermentative reactions did not correspond to those of the accepted *B. coli* types deviated in the presence of 0·025 c.c. of antiserum over 15 doses of complement, and even by varying the amount of antiserum one could not differentiate them from an A4 strain other than strain 1, *i. e.* the strain used for immunisation (Table XXV). Included among these were two strains which according to the usual criteria would not have been classed as typical *B. coli*, viz. two non-lactose-fermenters, and a

TABLE XXVI.—*Lysis of* 0·5 *c.c.* 5 *per cent. Ox Blood Suspension* + 5 *Doses immune body.*

Antiserum to Strain 3, B1 (*B. MacConkey* No. 74).	Bacillary emulsion 0·4 c.c.	Doses of complement.					Complement deviated by emulsion alone.	
		3 D.	5 D.	10 D.	15 D.	20 D.	3 D.	5 D.
0·005 c.c.	Strain 3, B (*B. No.* 74 *MacConkey*)	0	0	0	0	0	—	—
0·001 ,,		0	0	Dist.	Al. com.	Com.	Mk.	Com.
0·0005 ,,		0	Dist.	Mk.	Com.	Com.	—	—
0·0001 ,,		Trace	V. mk.	Al. com.	Com.	Com.	—	—
0·025 ,,	Strain 2, B1 (*B. No.* 74 *MacConkey*)	0	0	0	0	0	—	—
0·01 ,,		0	0	0	Trace	Al. com.	Mk.	Com.
0·005 ,,		0	0	Trace	Al. com.	Com.	—	—
0·005 ,,	Strain 1, B2	0	0	0	Trace	Dist.	—	—
0·001 ,,		0	Trace	Dist.	Mk.	V. mk.	V. mk.	Just c.
0·0005 ,,		0	Trace	Mk.	Al com.	Com.	—	—
0·0001 ,,		Trace	Mk.	V. mk.	Just c.	Com.	—	—
0·005 ,,	Strain 2, B2	0	0	0	0	Trace	—	—
0·001 ,,		0	Trace	Dist.	Mk.	Al. com.	Mk.	Com.
0·0005 ,,		0	Trace	Mk.	Just c.	Com.	—	—
0·0001 ,,		Trace	Mk.	Al. com.	Just c.	Com.	—	—

0·025 c.c. antiserum alone deviated 1 D. of complement.

strain which only fermented lactose after mutation; these strains all produced indol. *The fact that such Gram-negative bacilli behave in complement-deviation experiments with an antiserum to a strain of typical* B. coli *similarly to other typical organisms strongly suggests that lactose fermentation, which has always been considered one of the most important characters of* B. coli, *can hardly be taken as of more importance biologically than other sugar reactions.*

Among the 31 strains of sub-groups A, B, C and D examined in this way, three A types (Nos. 1, 9 and 22) did not react characteristically with the A4 and A3 antisera, *i.e.* the group reaction was absent in the case of the No. 1 and 22 strains and not well marked in the case of the No. 9 strain (Table XXIV). The No. 22 strain was isolated from a case of conjunctivitis in which it was present in pure culture; the Nos. 1 and 9 strains were of direct faecal

origin. On the other hand no representatives of the other sub-groups B, C and D exhibited any reaction with the A4 and A3 antisera.

TABLE XXVII.—*Lysis of* 0·5 *c.c.* 5 *per cent. Ox Blood Suspension* + 5 *Doses Immune Body.*

Antiserum to Strain 3, B1 (*B. No.* 74 *MacConkey*).	Bacillary emulsion 0·4 c.c.	Doses of complement.					Complement deviated by emulsion alone.	
		3 D.	5 D.	10 D.	15 D.	20 D.	3 D.	5 D.
0·05 c.c.	Strain 2, B1 (*B. No.* 74 *MacConkey*)	0	0	0	0	Trace	—	—
0·025 ,,		0	0	F. tr.	Dist.	Mk.	Mk.	Com.
0·01 ,,		0	0	Dist.	V. mk.	Com.	—	—
0·005 ,,		0	Trace	Mk.	Com.	Com.	—	—
0·05 ,,	Strain of B3	0	0	0	0	Dist.	—	—
0·025 ,,		0	0	Trace	Dist.	Mk.	V. mk.	Com.
0·01 ,,		0	Trace	Dist.	Mk.	Com.	—	—
0·005 ,,		0	Dist.	V. mk.	Com.	Com.	—	—
0·05 ,,	Strain of B10	0	0	0	0	0	—	—
0·025 ,,		0	0	0	Trace	Dist.	Dist.	Just c.
0·01 ,,		0	0	Trace	Dist.	Al. com.	—	—
0·005 ,,		0	Trace	Dist.	Al. com.	Com.	—	—
0·05 ,,	Strain of B10	0	0	0	0	0	—	—
0·025 ,,		0	0	0	0	Dist.	Dist.	Just c.
0·01 ,,		0	0	Dist.	Mk.	V. mk.	—	—
0·005 ,,		0	Trace	Dist.	V. mk.	Com.	—	—
0·05 ,,	Strain of B9	0	0	0	0	0	Mk.	Com.
0·05 ,,	Strain of B4	0	0	0	0	0	Mk.	Com.
0·05 ,,	Strain A1, (*B. No.* 71 *MacConkey*)	Mk.	Com.	Com.	Com.	Com.	Mk.	Com.
0·05 ,,	Strain of A6 (*neapolitanus*)	V. mk.	Com.	Com.	Com.	Com.	V. mk.	Com.
0·05 ,,	Strain A3 (*B. coli communis*)	Al. com.	Com.	Com.	Com.	Com.	Al. com.	Com.
0·05 ,,	Strain of C1	Mk.	Com.	Com.	Com.	Com.	Mk.	Just c.
0·05 ,,	Strain of C2	Mk.	Com.	Com.	Com.	Com.	Mk.	Com.
0·05 ,,	Strain of *D*6 *Coli anaërogenes.*	Mk.	Com.	Com.	Com.	Com.	Mk.	Com.
0·05 ,,	*B. paratyphosus* B	Dist.	Mk.	Com.	Com.	Com.	Mk.	Com.
0·025 ,,		Mk.	Al. com.	Com.	Com.	Com.	—	—
0·01 ,,		V. mk.	Com.	—	—	—	—	—

TABLE XXVII (*continued*).

Antiserum to Strain 3, B1 (*B. No 74 MacConkey*).	Bacillary emulsion 0·4 c.c.	Doses of complement.					Complement deviated by emulsion alone.	
		3 D.	5 D.	10 D.	15 D.	20 D.	3 D.	5 D.
0·05 c.c.	Strain of paracolon bacillus, lactose —, indol —, inosite —, glucose +, B 101	Dist.	Mk.	Al. com.	Com.	Com.	—	—
0·025 ,,		Dist.	V. mk.	Com.	Com.	Com.	—	Just c.
0·01 ,,		Mk.	V. mk.	Com.	Com.	Com.	—	—
0·005 ,,		Mk.	Com.	Com.	Com.	Com.	—	—
0·05 ,,	Strain of paracolon bacillus, B103	Trace	Dist.	Al. com.	Com.	Com.	—	—
0·025 ,,		Dist.	Mk.	Just c.	Com.	Com.	—	Com.
0·01 ,,		Dist.	V. mk.	Com.	Com.	Com.	—	—
0·005 ,,		Dist.	Com.	Com.	Com.	Com.	—	—
0·05 ,,	Strain of *B. coli mutabilis* B103 before mutation	Mk.	Al. com.	Com.	Com.	Com.	—	—
0·025 ,,		V. mk.	Com.	Com.	Com.	Com.	Just c.	Com.
0·01 ,,		V. mk.	Com.	Com.	Com.	Com.	—	—
0·005 ,,		Just c.	Com.	Com.	Com.	Com.	—	—
0·05 ,,	Strain of, B105, lactose — (+ after mutation), inosite —, indol —	Mk.	Com.	Com.	Com.	Com.	Just c.	Com.
0·05 ,,	Strain of B102, lactose — (+ after mutation), inosite —, indol —,	V. mk.	Com.	Com.	Com.	Com.	Just c.	Com.
0·05 ,,	*B. proteus*	Mk.	Com.	Com.	Com.	Com.	Just c.	Com.

0·05 c.c. of antiserum alone deviated 1 D. of complement.

Results observed with an antiserum to a B. type No. 1.—The specificity and group action of an antiserum to a strain belonging to one of the common types of sub-group B was also investigated. The antiserum to strain 3, B1 (*B. MacConkey* No. 74), whose agglutinating properties have already been referred to, was employed for this purpose.

It was found that the serum displayed no specificity either for the individual strain or the type to which it belonged. In fact certain strains of other different types within the sub-group B exhibited as much affinity (as determined by complement-deviation tests) for the serum as the strain

used for immunisation (Table XXVI). The group reaction was strictly limited to types belonging to the B sub-group. Thus with a number of strains of sub-group A, C and D practically no deviation was obtained (Table XXVII).

In the case of sub-group A it was found that by deviation tests non-lactose-fermenters and organisms which only fermented lactose after mutation could be classed along with the typical lactose-fermenting types. In sub-group B non-lactose-fermenters (*B. paracolon* types) and strains which developed lactose-fermenting mutants (*B. coli mutabilis* types) could not be identified with the lactose-fermenting types, *i.e.* the group action of an antiserum to a lactose-fermenter was limited to those types which fermented lactose in primary culture.

As a result of these serological findings some indication has been elicited of the biological grouping of the different cultural types of coliform bacilli.

The results may be summarised as follows:

In sub-group A (gas-forming, indol +, inosite −, gelatin −) as determined by tests with antisera to types 1, 2, 3 and 4, there is a high degree of specificity of the agglutinin for the individual strain used for immunisation, but no evidence of specificity for the type, or group action towards other organisms of the sub-group; there is a relative specificity of the complement-deviating immune body, as determined with antisera to types 1, 3 and 4, for the individual strain but not for the cultural type; there is, however, a well-marked group reaction limited to strains of the sub-group irrespective of other cultural reactions (*e.g.* lactose, dulcite, saccharose, inulin fermentation, motility), and not extending to the B, C or D sub-groups, *B. paratyphosus B*, or *B. proteus*.

In sub-group B, as determined by observations with antisera to types 1 and 2, there is a more limited degree of specificity of agglutinating antisera for the individual strain but not complete specificity for the cultural type: there is absence of relative specificity of the complement-deviating antibody (antiserum to type I) for the individual strain, and the group reaction, as far as my observations go in the case of the types tested, is limited to the lactose-fermenting types, and does not extend to the A, C or D sub-groups, the non-lactose-fermenting types, of the B sub-group, the types which only fermented lactose after mutation, *B. paratyphosus B* or *B. proteus*.

While among the indol +, inosite −, gas + types lactose-fermentation appeared of no more significance than certain other reactions, in the case of the indol − inosite −, gas + types the lactose-fermenting types seemed to be separately grouped as apart from the non-lactose-fermenters and those which only fermented lactose after mutation.

Also in the case of two types of non-lactose-fermenters of the B sub-group exact specificity of the agglutinin for the type or species was noted,

and this also differentiated these organisms from the lactose-fermenting types.

The Comparative Resistance to Brilliant Green of Different Types of Coliform Bacilli with Reference to the Classification of these Organisms.

In the course of certain observations on the enrichment of *B. typhosus* by culture from faeces in fluid media containing brilliant green (Browning, Gilmour and Mackie), it was noted that different types of *B. coli* exhibited different degrees of susceptibility to this chemical. The "typical" varieties (sub-group A, types 1, 2, 3, etc.) were completely inhibited in their growth on culture medium by concentrations of brilliant green which had no effect on *B. typhosus*, but it was noted that the inosite fermenters (sub-group C) on the contrary exhibited a resistance to the dye greater even than that of the typhoid bacillus.

As this appeared to be a striking difference between two *B. coli* sub-groups already classified separately on an entirely different basis, there seemed some likelihood that the study of the behaviour of different coliform types towards this dye might throw some further light on the biological relationships of the various cultural types.

For this purpose a series of representative strains from the four sub-groups were tested as regards the inhibition of their growth in peptone-water-agar by different quantities of brilliant green incorporated in the medium.

The concentrations of the dye tested were 0·16, 0·22, 0·32, 0·42 c.c. of a 1:10,000 watery solution in 10 c.c. of the medium.

Emulsions of the various organisms were made in sterile salt solution, of such density that the fluid showed a mere trace of turbidity to the eye, and cultures were made by taking one loopful of the emulsion and spreading it on the medium in stroke form (one stroke only). On ordinary medium this inoculation produced an abundant line of growth along the needle tract. One plate was, of course, used to accommodate several strokes from different organisms.

The plates were incubated for forty-eight hours and readings were made after twenty-four and forty-eight hours.

With two exceptions all the sub-group A organisms tested proved relatively susceptible (as compared with *B. typhosus*) to the dye, including non-lactose-fermenters (Table XXVIII); the exceptions were (1) a strain of type 9 and (2) a strain of type 22 (isolated from a case of conjunctivitis); another strain of type 9, however, corresponded in its behaviour to the other A types. It is noteworthy that these two strains also differed in the complement-deviation experiments from other A types.

TABLE XXVIII.—*Brilliant Green* 1 : 10,000 *watery solution per* 10 *c.c. peptone-water-agar. Observations after* 24 *hours' incubation.*

Strains of	1 0·16 c.c.	2 0·22 c.c.	3 0·32 c.c.	4 0·42 c.c.
Sub-group A.				
Type 1 (*B. MacConkey*, No. 71)	++	—	—	—
„ 3 (*B. vesiculosus*)	+	+	—	—
„ 3	++	—	—	—
„ 5 (*B. Schafferi*)	+	—	—	—
„ 1	++	—	—	—
„ 6 (*Neapolitanus*)	+	—	—	—
„ 4 (*B. Grünthal*)	+	—	—	—
„ 3	+	+	—	—
„ 6	+	—	—	—
„ 15	+	—	—	—
„ 30	+	—	—	—
„ 2	++	—	—	—
„ 35 (*Lactose* —)	—	—	—	—
„ 2	+	—	—	—
„ 9	+	+	—	—
„ 13	—	—	—	—
„ 28	+	—	—	—
„ 33	+	—	—	—
„ 12	++	—	—	—
„ 9	+++	+++	++	—
„ 2	++	—	—	—
„ 4	+	—	—	—
„ 3	+	—	—	—
„ 1	++	—	—	—
„ 22	++++	+++	++	—
B. typhosus	++++	++++	++	—
B. proteus	+	—	—	—
Sub-group B.				
Type 1	++++	++++	++	++
„ 9	++++	++++	++	+
„ 10	++++	++++	++	++
„ 2	++++	++++	++	—
„ 2	+++	+++	++	—
„ 10	+++	+++	+	—
„ 1	++++	+++	++	+
„ 101 (*paracolon*)	—	—	—	—
„ 104	—	—	—	—
„ 103 (*paracolon*)	—	—	—	—

TABLE XXVIII (*continued*).

Strains of	1 0·16 c.c.	2 0·22 c.c.	3 0·32 c.c.	4 0·42 c.c.
Type 106	—	—	—	—
„ 103. Developed lactose-fermenting mutant	++++	++++	++++	++++
„ 102. Developed lactose-fermenting mutant	++++	++++	++++	++++
„ 105. Lactose - fermenting mutant	++++	++++	++++	++++
„ 102. Lactose - fermenting mutant	++++	++++	++++	++++
„ 103. Lactose - fermenting mutant	++++	++++	++++	++++
Sub-group C.				
Type 1	++++	++++	++++	++++
„ 2	++++	++++	++++	++++
„ 5	++++	++++	++++	++++
„ 1	++++	++++	++++	++++
„ 2	++++	++++	++++	++++
„ 4	++++	++++	++++	++++
„ 3	++++	++++	++++	++++
„ 9	++++	++++	++++	++++
Sub-group D.				
Type 1	++++	++++	+++	+++
„ 3	—	—	—	—
„ 5	—	—	—	—
„ 7	++	—	—	—
„ 4	++++	+	—	—
„ 2	+	—	—	—

The strains of sub-group B showed some variation in their resistance to brilliant green, as might have been expected from the biological differences elicited by the serological tests.

Those belonging to the series 1–11 (fermenting lactose in primary culture) all showed a higher degree of resistance to the dye than the A types, and equal to or slightly greater than that of *B. typhosus*. Those types which developed lactose-fermenting mutants exhibited a high degree of resistance, *i. e.* much greater than that of series 1–11 or *B. typhosus*, while the paracolon types were apparently less resistant even than the A types.

In the B sub-group, therefore, the various types could be classified into three categories according to their resistance to brilliant-green correlated with certain cultural characters and reactions.

In the C sub-group all the strains tested exhibited a high resistance to brilliant green, equal to that shown by the mutating strains of sub-group B.

In the D sub-group there was some variation in the susceptibility of different types, but the number of strains available for testing was too limited to draw any inferences from the results.

These findings correlated with the serological observations are of considerable interest; from the serological study it was concluded that the gas +, indol +, inosite – types could be grouped together apart from the other organisms of the *B. coli* group. The tests carried out with these organisms growing on brilliant green media also show the striking distinction between organisms of the sub-group A on the one hand and the C types and also certain of the B types on the other.

While the A types (with few exceptions) are all more or less similar in their behaviour, and the same is also true for the C types, various B and D types behave differently.

In the B sub-group the lactose-fermenters were differentiated serologically from the paracolon varieties and those which only fermented lactose after mutation; in the brilliant green resistance tests a corresponding difference was established.

These experiments, therefore, apart from the practical bearing they had in connection with the brilliant green enrichment process for the isolation of *B. typhosus*, were of considerable interest in correlation with the previous work on the classification of the *B. coli* group.

VARIATION AMONG THE COLIFORM BACILLI.

Variation in Gas Production.

Among these organisms certain anomalies have been noted as regards this property (Mair, Wilson and others); thus strains when first isolated may show complete absence of gas production, but on repeated subculture develop this property. Reference has already been made to strains of paracolon bacilli (p. 329) which in primary culture simulated *B. typhosus* in their cultural reactions. The possibility of this variation must be considered, therefore, in the practical identification of intestinal bacilli. A *B. paratyphosus* A in the first cultures made after isolation may show complete absence of gas production, and if it only ferments dulcite slowly, as is often the case, it may thus simulate *B. typhosus* in cultural characters. *B. dysenteriae* Shiga may also be simulated by a non-motile organism which after repeated subculture ferments glucose with gas production, though in primary culture it produces no gas (of glucose, lactose, dulcite, saccharose, mannite, maltose, only glucose fermented).

My attention was first drawn to this variation by the occurrence of a strain of *B. coli* (B1), which, when tested shortly after isolation, produced gas from dulcite only, and when re-tested after a month's culture was found to have attained the power of producing gas from lactose and saccharose though still non-gas-producing in glucose. Later it also acquired the power of fermenting glucose with gas formation.

Though the absence of gas production in the case of *B. typhosus* and *B. dysenteriae* is known to be a stable character of these organisms, the question arose as to whether "*anaërogenes*" types of coliform bacilli simply represented variant strains of *aërogenes* types.

While certain strains have been noted which immediately after isolation produced no gas from *any* of the sugars fermented (*e. g.* B101), it was found that in many cases gas production was only absent in certain of the sugar tests (*e. g.* strain of B1 quoted above); also, as a general rule, such organisms after a few subcultures quickly developed the property of gas production, *i. e.* the character seemed to be only in abeyance. On the other hand, the various strains classified as "*anaërogenes*" (sub-group D), even after repeated subculture and after being kept in artificial growth for long periods, still remained non-gas-producing.

It has been shown by Penfold that by growing *B. coli* on monochloracetic acid agar a variant strain could be selected out which differed from the original in the absence of gas formation in certain sugars. With a view to determining the possibility of transmuting an *aërogenes* type into an *anaërogenes* variety, certain *B. coli* strains were submitted to Penfold's procedure.

Method.—The monochloracetic acid was made up in a 10 per cent. watery solution, and after having been made slightly alkaline to litmus by adding sodium carbonate, was sterilised by filtration through a Maassen filter. The solution was then incorporated in a 2 per cent. peptone-water-agar in measured proportions. The percentages indicated below are expressed in terms of the amount of the acid in the quantity of medium used for plating.

In the first experiment a series of plates each of 10 c.c. of monochloracetic-acid-agar, the acid being in the following proportions:

1		2		3		4
0·05 per cent.	.	0·1 per cent.	.	0·5 per cent.	.	1·0 per cent.

were inoculated with a typical *B. coli communis* strain. On plate 1 a normal amount of growth was obtained but the colonies varied considerably in size. On plate 2 the difference in the size of the colonies was more marked and many of the larger colonies showed papillae as described by Penfold. On plates 3 and 4 no growth appeared. A subcultivation on ordinary agar was made from a large colony on plate 2, and from this plates containing the following concentrations of monochloracetic acid were inoculated as before:

1	2	3	4	5
0·2 per cent.	0·3 per cent.	0·4 per cent.	0·5 per cent.	0·7 per cent.

On all these plates abundant growths were obtained and all the colonies were of the large type. A subcultivation was again made on ordinary agar from plate 5 and from this plates containing the acid in still higher proportions were inoculated.

1	2	3
0·5 per cent.	1 per cent.	2 per cent.

Growth was abundant on plates 1 and 2; in the case of plate 3 the growth was slower in appearing, but ultimately a few large colonies developed. Thus a monochloracetic acid resistant strain was selected out, and subcultures on ordinary medium when tested were found to produce acid only from glucose, acid and considerably reduced amount of gas from lactose and galactose, acid and gas (in a slightly reduced amount) from dulcite and mannite.

A similar test was carried out with a sub-group A type 1 strain; the selected strain capable of growing on 2·5 per cent. monochloracetic acid agar showed also absence of gas production in glucose, considerably reduced gas production in lactose and galactose, and slightly reduced gas production from dulcite and mannite. Other strains of typical *B. coli* and a *B. proteus* were tested with similar result as regards the particular sugars of the above series fermented.

The results differed from those of Penfold* in that the only "sugar" (of 2 monosaccharides, a disaccharide and 2 hexahydric alcohols) from which these variants completely failed to produce gas was glucose, though in the case of lactose and galactose there was some depression of the gas-producing property.

All these variants maintained their stability as regards the new character even after several months' subculture on ordinary agar, but by subculturing every day in glucose peptone water for a week, a reversion of the strain was noted and the power of producing gas was regained. Harden and Penfold found that, from the biochemical standpoint, the change was more a quantitative than a qualitative one.

Thus from my observations it was only possible to completely abolish the gas production of *B. coli* in the case of glucose, and it was also shown that the original character could be easily regained under certain conditions. It was in no way possible to select from an *aërogenes B. coli* type a corresponding *anaërogenes* variety.

The absence of gas production after several subcultures may, therefore, be regarded as a fundamental character of certain coliform types.

* Penfold's variant strains showed absence of gas production in lactose as well as glucose.

VARIATION IN BIOCHEMICAL CHARACTERS AMONG THE COLIFORM BACILLI.

Such variations have been observed occurring spontaneously in culture medium, and afford some indication of the process of evolution going on among these organisms under natural conditions. The marked diversity of types in this group as regards cultural reactions has been well shown by the work of all those who have studied these organisms, and in the serological observations already recorded the highly specialised characters of individual strains have been alluded to; it may be assumed, therefore, that new types or species are constantly being developed from pre-existing varieties, and that these bacilli tend to acquire new characters which are not spontaneously lost, *i. e.* that the tendency is a progressive one and represents the origin of new species.

In 1907 Massini* described a non-lactose-fermenting Gram-negative bacillus (*B. coli mutabilis*) which on Endo-agar developed lactose-fermenting mutants represented by red papillae on the pale colonies of the original strain, and after further subculture as red colonies. This was corroborated by Burk and later by Müller in the case of the fermentation of other carbohydrates.

In studying the fermentative reactions of coliform bacilli it has been noted that certain strains may not show any obvious change in a particular sugar, *e. g.* lactose, until the lapse of several days; organisms of this type were investigated by Penfold, who showed that these slowly fermenting strains were primarily non-lactose-fermenters which in fluid media threw off lactose-fermenting variants, the variant producing rapid fermentation of the sugar. Thus the obvious difference between the variant and the original strain lay in the rate of fermentation of lactose. The strains studied were characterised by the formation on differential medium (such as MacConkey's neutral red lactose agar or Endo-agar) of pale colonies, which developed after a few days red papillae as in the case of Massini's strain.

A number of strains were met with in the course of my own study of the *B. coli* group which, though primarily non-lactose-fermenters, in fluid medium containing lactose apparently threw off lactose-fermenting variants. All these organisms formed pale colonies on MacConkey's agar; certain of them corresponded to the type described by Penfold in developing red papillae. By subculturing the papillae on another plate of MacConkey's medium, red colonies were grown representing a variant which differed from the original strain in producing rapid fermentation of lactose in fluid medium, whereas the sugar was only fermented after several days (and often without gas production) by the original strain.

Some of these organisms, on the other hand, showed no evidence of mutation on solid media containing lactose (*e. g.* MacConkey's agar), *i. e.* red papillae were not observed, but on subinoculating from the fluid lactose

* Reported also by Neisser (1906).

TABLE XXIX.—*In this table A = acid; G = gas, the amount of gas production being indicated by G+, G++, G+++; C = clot (from milk).*

Strain of type.	Days' incubation.	Lactose.	Dulcite.	Saccharose.	Adonite.	Milk.	
B102	1	—	—	—	—	—	Colonies on MacConkey's agar developed red papillae after 3 days.
	2	—	—	—	—	A	
	5	A	—	—	—	AC	
Variant	1	AG+++	—	—	—	AC	
B104	1	—	—	—	—	A	Colonies on MacConkey's agar developed red papillae after 4 days.
	2	—	—	—	—	A	
	5	AG+	—	—	—	AC	
Variant	1	AG+	—	—	—	AC	
D1	1	—	—	—	—	—	Absence of papilla formation.
	2	—	—	—	—	—	
	5	—	—	—	—	—	
	10	A	—	—	—	A	
Variant	1	A	—	—	—	A	
	2	A	—	—	—	AC	
B107	1	—	—	—	—	—	Absence of papilla formation.
	2	A	—	—	—	A	
	5	AG+	—	—	—	A	
Variant	1	AG+++	—	—	—	A	
	2	AG+++	—	—	—	AC	
A19	1	—	—	—	—	A	Absence of papilla formation.
	2	—	—	—	—	A	
	5	A	—	—	—	AC	
	10	AG+	—	—	—	AC	
Variant	1	AG++	—	—	—	AC	

Note.—In all 5 strains were noted corresponding in cultural reactions to B102 and also developing lactose-fermenting variants (represented by red papillæ on the colonies on MacConkey's agar).

TABLE XXIX (*continued*).

Strain of type.	Days' incubation.	Lactose.	Dulcite.	Saccharose.	Adonite.	Milk.	
A19	1	—	—	—	—	—	Absence of papilla formation.
	2	—	—	—	—	A	
	5	AG+	—	—	—	A	
Variant	1	AG++	—	—	—	AC	
B103	1	—	—	—	—	—	Absence of papilla formation.
	2	—	—	—	—	—	
	5	—	—	—	—	—	
	10	A	—	—	—	A	
Variant	1	AG++	—	—	—	AC	
B8	1	—	—	—	—	—	Absence of papillae from colonies on neutral red dulcite agar.
	2	—	—	—	—	—	
	5	—	—	—	—	—	
	10	—	A	—	—	—	
Variant	1	—	AG+	—	—	—	
B10 (after mutation)	1	—	—	—	—	—	Absence of papillae from colonies on neutral red adonite agar.
	2	—	—	—	—	—	
	5	—	—	—	—	—	
	10	—	—	—	AG+	—	
Variant	1	—	—	—	AG++	—	
B106	1	—	—	—	—	—	Absence of papilla formation on MacConkey's medium.
	2	—	—	—	—	—	
	5	—	—	—	—	A	
	10	A	—	—	—	A	
Variant	1	AG+	—	—	—	AC	
A28	1	—	—	—	—	—	Colonies on saccharose neutral red agar developed red papillae after 4 days.
	2	—	—	—	—	—	
	5	—	—	—	—	—	
	10	—	—	AG+	—	—	
Variant	1	—	—	AG++	—	—	

TABLE XXIX (*continued*).

Strain of type.	Days' incubation.	Lactose.	Dulcite.	Saccharose.	Adonite.	Milk.	
B8	1	—	—	—	—	—	Absence of papillae from colonies on saccharose neutral red agar.
	2	—	—	—	—	—	
	5	—	—	A	—	—	
Variant	1	—	—	AG+	—	—	
B105	1	—	—	—	—	—	Colonies on MacConkey's agar developed red papillae after 3 days.
	2	—	—	—	—	A	
	5	A	—	—	—	A	
	10	A	—	—	—	AC	
Variant	1	AG+	—	—	—	AC	
B103	1	—	—	—	—	—	Colonies on MacConkey's agar developed red papillae after 3 days.
	2	—	—	—	—	—	
	5	A	—	—	—	A	
	10	A	—	—	—	AC	
Variant	1	AG+	—	—	—	AC	
A34	1	—	—	—	—	—	Absence of papillae from colonies on MacConkey's agar.
	2	—	—	—	—	—	
	5	—	—	—	—	A	
	10	A	—	—	—	A	
Variant	1	AG+	—	—	—	A	
	2	AG++	—	—	—	AC	
A35	1	—	—	—	—	—	Absence of papillae from colonies on MacConkey's agar.
	2	—	—	—	—	—	
	5	A	—	—	—	A	
	10	A	—	—	—	A	
Variant	1	AG++	—	—	—	AC	
B101	1	—	—	—	—	—	Absence of papillae from colonies on saccharose agar.
	2	—	—	—	—	—	
	5	—	—	—	—	—	
	10	—	—	A	—	—	
Variant	1	—	—	AG	—	—	

medium in MacConkey's agar a mixture of pale and red colonies was obtained; the pale colonies corresponded to the primary strain, the red colonies to the variant.

Similarly, strains were noted which mutated as regards the fermentation of other sugars, *e.g.* dulcite, saccharose, adonite.

The variations exhibited by these strains and the differences between the original and the variant strain are shown in Table XXIX.

It is noteworthy that the majority of these mutating strains were of the B sub-group. While most of these variations were in the fermentation of lactose, it has been shown how similar mutations may occur in the fermentation of dulcite, saccharose and adonite.

It may also be noted here that no variations have been met with as regards the fermentation of inosite. Similarly the presence or absence of indol formation has been found to represent stable characters. Of course quantitative variations in indol production have been observed, and it has been shown how the amount of indol produced may be increased or diminished under certain conditions (Peckham, Horrocks). A considerable proportion of all the coliform strains examined were re-tested after two to three months from the time of their original classification, and in all cases indol formation or the absence of this property proved stable.

Variation in Cultural Characters Associated with Variation in Agglutinability.

It has been shown that variation in biochemical reactions is not associated with any change in the serological characters of the strain (Penfold) and this was confirmed in the case of one of the mutating strains described above (p. 339).

Variations in colony characters of certain *B. coli* strains produced by growth on an inhibitory medium (*i.e.* containing brilliant green) have, however, been found to be associated with considerable quantitative variation in agglutinability of the variant strains as compared with the original (Mackie).

It can be understood how a group of bacteria which are constantly developing mutants with new biochemical characters has come to represent in the course of time a considerable number of different cultural types as seen in the *B. coli* group; in the same way constant variation in serological characters, without change in biochemical reactions, would explain the highly specialised serological characters of the individual strain and the absence of specificity of an antiserum for the cultural type.

The process of evolution and origin of new types going on among these Gram-negative bacilli is not only of the greatest biological interest, but the study of these variations elicits some explanation of the great diversity of types and also the highly specialised serological characters of coliform bacilli.

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A CONTRIBUTION TO THE STUDY OF THE RAINFALL MAP OF SOUTH AFRICA.*

By J. R. Sutton.

(With thirteen Maps.)

"When the clouds shake their hyssops, and the rain
Like holy water falls upon the plain,
'Tis sweet to gaze upon the springing grain
And see your harvest born."—*Ledwidge.*

1. Introduction.

In the rainfall tables at the end will be found full particulars of the mean monthly and mean annual rainfall for 567 stations in South and East Africa. These have been computed from all the information available in the published reports of the meteorological services of the various States. Occasional items have been extracted from the 'Meteorologische Zeitschrift,' the 'Quarterly Journal of the Royal Meteorological Society,' Symons's 'Meteorological Magazine,' and the *Northern News.* Besides this the directors of some of the services have kindly furnished special information on request; friends have obtained and forwarded returns from stations in the Bechuanaland Protectorate; and resident magistrates and police officers have helped materially. Consequently it is now possible to give a very much larger and truly representative account of South African rainfall than it was possible to give in a previous discussion.†

The tabulated averages now given, dealing with some 8800 years of record altogether, have, with few exceptions, been computed by me alone. The work has been gone over two or three times in order to ensure accuracy, but with such a mass of material it would be a wonder if there were no mistakes at all. Certainly there are not many.

The aim throughout has been to use all existing records running into ten years or more, and in areas where gauges are numerous this rule has been

* The tables and maps here given were prepared five years ago; but, for various reasons, it has not been possible to publish them before.

† J. R. Sutton, "An Introduction to the Study of South African Rainfall," 'Trans. Phil. Soc. S. Afr.,' May, 1904. This dealt with 160 stations having records of long periods.

adhered to. But in areas not well supplied with gauges records of shorter period have had to be admitted, since it has seemed better to get an approximation to the average rainfall at such places than to ignore them altogether. Naturally the means given in the table are not all of the same value; short-period records cannot be expected to give such good mean values as long-period records do, and all observers are not equally faithful.

A common fault in every country is the omission to register small falls of rain, because, forsooth, the observer thinks them too contemptible to bother about. A scrutiny of the returned number of days of rain is sufficient in most cases to reveal this fault; and when there are two or three gauges in one town the record containing the greatest number of rainy days is usually taken as the standard. When there is only one gauge, even when the number of days of rain reported seem to be rather too few, the record of quantity has been used for what it is worth. It is a pity that some observers do not realise that the trouble they take in measuring the heavy falls of rain is largely labour in vain, in a scientific sense, unless they take pains over the smaller falls. Generally speaking the longer records are the most trustworthy, especially when they are the work of one observer. This is because the observer who has enough intelligent energy to go on recording the rainfall year after year does not shirk the measurement of the smaller quantities. Nevertheless there is at least one long-period record in the Cape Province of little scientific value simply because only the heavy falls of rain have been regarded as worth bothering about. It cannot be insisted upon too often that the lighter rains must be as carefully looked after as the heavier ones. For one thing, if there be a secular change of climate anywhere it must proceed very slowly, and the facts can only be discovered by a uniform system of observation which does not neglect small things.

The latitudes, longitudes and altitudes stand, as far as possible, for the latest determinations. In a few cases they have been measured off roughly from maps. The numbers under the heading "years" do not necessarily stand for an unbroken period, although they mostly do. Sometimes they represent two or more periods of observation alternating with longer or shorter intervals during which no records were kept. In such cases the number of years is really the quotient of the number of months divided by twelve. Thus at Lilyfontein (III A, 44) from 1885 to 1908 only ten full years of observation are known; but there were further odds and ends running into fifty-eight months, making 178 months in all, which we call fifteen years.

Occasionally a rain record has been started at one spot, and continued at another not far away. If the aspects and altitudes of the two places are not materially different such a record has been regarded as continuous. For instance a part of the Dumbiedykes rainfall was really observed at Geelbeks Vley a few miles off; and the means for Sea Point have been made

up from quite a number of separate records from here and there in a small area. One or two combinations of this sort have been done for East African stations, but some amount of caution will be requisite before accepting the results.

In only one instance has any interpolation been attempted, namely, for the Devil's Peak lower gauge, in which an eleven years' record period, 1896 to 1906, has been proportionally reduced in harmony with the Nursery and Blockhouse gauges to the thirteen years' period 1896 to 1908.

With some slight modifications, the rainfall areas I to XVII are those used by the late Meteorological Commission of Cape Colony, and established, so to speak, under those numbers by many years of use. Some of these areas are large, and it has been thought best to subdivide them. Thus Section IX has been subdivided into IX A (West) and IX B (East). Sections XVIII to XXX are additional.

The mean monthly falls for each section, or subdivision, have been computed, not necessarily by way of showing the average fall over the area (though it probably does show that with some degree of precision), but rather to trace the tendency of the monthly variations—which is the wet season and which the dry.

2. Notes on the Rainfall Tables.

I. *Cape Peninsula.*

This small area, scarcely larger than the smallest English county, has a distribution of rainfall probably more varied than that of any other equal area in all Africa. From its position on the west side of the Continent it stands within a dry region, but the contour of the land alters the conditions, and transforms the dryness into an abundant precipitation over the greater part, which rises like an oasis out of an arid region. The stations in the table showing the least rainfall are Blaauwberg Strand (I, 2) and Cape Point (I, 3), with annual averages of 13·94 in. and 12·70 in. respectively, these two stations being some thirty miles apart, one near the extreme north and the other near the extreme south of the peninsula. But according to Sparrman it never rains at all on the flats immediately to the south of Table Mountain*—a remarkable fact if true, seeing that Wynberg (I, 19), on the edge of the flats, has no less than 44½ in. a year. Along the Atlantic side of the peninsula the rainfall is only moderate, averaging about 20 in. a year, Signal Hill (I, 13) with 18·52 in. and Sea Point (I, 12) with 21 in. The east, *i.e.* the landward side, is, however, wet, ranging between Rondebosch (I, 10) 42·56 in., Platteklip (I, 8) 45·34 in., Bishop's Court (I, 1) 57·90 in. The effect of altitude is well shown by the Devil's Peak gauges, the lower gauge (I, 4) at something over 1000 ft. 47·02 in., the

* 'A Voyage to the Cape of Good Hope,' Second Edition, 1786, p. 34.

Blockhouse, at 1500 ft., 58·67 in. The slopes of Table Mountain show the same tendency, the rainfall at St. Michael's (I, 71) being not far short of 76 in. a year, while Disa Head, a dry station for its altitude, more than 500 ft. lower, has only 40 in. So far as is known the wettest place in the peninsula is Maclear's Beacon on the top, and near the eastern escarpment of the mountain (I, 16A), with an annual average of 89·30 in.*

The annual curve of rainfall is fairly simple, with a maximum in June and a minimum in February. But there is just a tendency towards a small secondary maximum in August, in response to continental conditions.

II. *South-Western Cape Province.*

This area includes the districts of Caledon, Stellenbosch, Paarl, Robertson, Tulbagh, Ceres, and Worcester south of the Hex River. The mean annual rainfall varies from 11·43 in. at Worcester (II, 38) to 40·89 in. at Ceres (II, 21), only twenty miles away. The majority of the stations have upwards of 20 in. a year. Probably one of the wettest stations in South Africa is situated in this area, *i. e.* at Berg River Hoek, No. 9 Gauge, on the western slope of the Hottentot's Holland Mountains, in lat. 33° 55′, long. 19° 4′. The altitude is not given. Two years of observation at this spot gave a mean rainfall of no less than 115 in. a year.

The annual curve of rainfall resembles that of I, but the August maximum is more strongly marked.

III. *Western Cape Province.*

Comprises the whole western side of Cape Colony from Bok Point to the Orange River. It has been subdivided here into III A (Namaqualand), and III B (the districts of Van Rhyns Dorp, Clanwilliam, Piquetberg, and Malmesbury). The rainfall decreases rapidly as we go north, ranging all the way from 24·21 in. at Saron (III B, 57) to 2·28 in. at Port Nolloth (III A, 47). For Namaqualand, Lilyfontein has quite an exceptional rainfall.

The August maximum, though quite obvious, is somewhat more uncertain than it is in II. Also as we go north we find a retrogression of the first maximum into May, and a corresponding retreat of the minimum into January; inland, at Pella (III A, 46), the maxima one in March and October, the minima in July and November.

IV. *Southern Cape Province.*

Comprises the whole of the south coast districts of Cape Colony from Cape Agulhas to Algoa Bay. The rainfall increases gradually on the whole

* See T. Stewart, "The Rainfall of Table Mountain," 'Trans. R. Soc. S. Afr.,' iii, 1913. The averages for the "Additional Stations" are taken from this paper. As much as 36·58 in. in one month (August, 1899) has been recorded at Maclear's Beacon.

from west to east, and from the coast inland to the outer slopes of the Langebergen and Outniquas Mountains. On the other side of the coast ranges, whose spurs, jutting south-east, form the heads of Cape St. Francis and Cape Recife, the fall is again less, as Uitenhage (IV B, 80), 17·09 in., and Dunbrody (IV B, 73), 15·58 in.

In the western half of this area there is a long-drawn-out maximum of precipitation from February to May, and a shorter one in October. In the eastern half there are maxima from March to May and in September–October. In both halves the minima are in January and July.

V. *Southern Karroo.*

The Western half, called the Little Karroo on some maps, of this area is the terrace which lies between the Langebergen and Groote Zwartebergen, forming as it were the first step up from the coast plains. The rainfall is poor, the rain-bearing clouds having deposited much of their excess of moisture on the southern slopes of the first range of mountains inland. There are two maxima in the year, roughly in March and October, but varying in epoch from one station to another. The summer minimum is also of somewhat uncertain epoch, but the winter minimum is fairly sure in July.

The eastern half stretches across the spurs, which strike seawards to the north of Cape St. Francis. If there were any truth in the popular idea of "south-east rain-bearing winds" this area would have a copious rainfall instead of less than Uitenhâge and Dunbrody. There are maxima near the times of the equinoxes, minima about the middle and end of the year.

VI. *West Central Karroo.*

The Great Karroo of the maps. It is bounded on the north by the Nieuwveld Range, on the south by the Groote Zwartebergen, and on the west by the Bontebergen, its eastern boundaries being ill-defined along the middle reaches of the Groote River.

The western half, *i. e.* VI A, may be regarded as the second step up from the coast belt to the table-land, and shows the effect of a still further depletion of the clouds in the second range of mountains inland. Only one station in this area has a good rainfall, namely Zwartberg Pass (VI A, 101), in the mountains, with 27·41 in. There are two annual maxima, about the time of the equinoxes, with minima in July and November.

The eastern half, VI B, stretching from the Nieuwveld Range to the Baviaans River, differs from the western half not only in its greater rainfall, but more particularly that it has only one maximum and minimum of precipitation in the year, the former being in March and the latter in July. On this account Beaufort West would perhaps have been more at home in VI B. Nelspoort (VI B, 104) and Lower Nelspoort (VI B, 105) are similarly

situated and only some four or five miles apart, and hence each gives practically the same information.

VII. *East Central Karroo.*

Comprises the districts of Graaff Reinet, Somerset East, Jansenville, and a portion of Aberdeen. The rainfall is of a similar character to that of VI B. Somerset East (VII, 122) is, properly speaking, a sort of salient from X, but the region north, south and west of Somerset East is typical Karroo.

VIII. *Northern Karroo.*

Extending from Namaqualand on the west to the Great and Little Winterberg on the east; is actually the southern portion of the table-land. The western half, VIII A, of this has generally a single maximum and minimum of rainfall in the year, *i.e.* in March and August. Some of the stations on the lower slopes to the west-south-west still show, however, the double maximum and minimum of VI A. In the direction of Namaqualand the country is very sparsely inhabited, and only one record of rainfall, namely that of Brandvlei (VIII A, 129), has so far been discovered in it, and that for only five years. The Gannapan (VIII A, 133) numbers are almost certainly too low. The eastern half, VIII B, has the March maximum, but the minimum is nearly a month early, falling in July.

IX. *Northern Cape Province.*

This area is bounded by Namaqualand on the west to the Orange River Colony on the east, and includes all the northern provinces of Cape Colony. Upington is on the north bank of the Orange River, The Halt is some distance to the north of the river on the border of Great Namaqualand, both these stations being really in Gordonia. Van Wyks Vlei would perhaps be better included in VIII A, excepting that the Karreebergen to the south cut it off from that area. The annual curve of rainfall is of the simple type, with one maximum in March and one minimum in August. The rainfall at Groot Boetsap is exceptionally great considering its position. The Kimberley rainfall includes Kenilworth, and goes back to 1874.

X. *South-Eastern Cape Province.*

This region of abundant mean rainfall, watered by the Buffalo, Keiskama, Kei, Kunap, Great Fish, Kowie and Bushman Rivers is better represented by rain-gauges than any other excepting the Cape Peninsula. And it has been possible to select no less than twenty-eight stations, each having a record extending over more than twenty years of, generally speaking, good observing.

The southern slope of the Amatola Mountains in this area is the wettest

known spot in Cape Colony outside Table Mountain and the Hottentot's Holland, and includes Evelyn Valley (X 190) with 65·17 in. a year, and the Hogsback with 43 in. With the exception of Alicedale (X, 182) and Daggaboer (X, 187) no station in this area has a smaller mean annual rainfall than 20 in.; but these two stations, which are on the extreme west of X, might very well have been included in VII.

On the whole there is a single maximum and minimum in the year, namely, about February or March and July respectively. But several stations, particularly those not far from the coast, show a second maximum in October–November, *e.g.* East London, Port Alfred, and Alexandria (X, 189, 203 and 180 A).

Though well watered on the whole this area is subject to droughts lasting for some weeks. At Alexandria there has been one November with 11 in., and the next November not half an inch. It appears that occasionally the Karroo conditions of VII push right down to the coast.

XI. *North-Eastern Cape Province.*

Includes the high country lying between the Orange Free State and X. It is now fairly well supplied with gauges and good observers, and sixteen have records of over twenty years' duration. It has a pretty good rainfall of the simple type, with its maximum in February and its minimum in July. The rapid increase of quantity from November to December is noteworthy. The area is crossed by the watershed of the Stormbergen, but this range has no such effect upon the rainfall as the ranges further west, the stations to the north of it having at least as good a fall as those to the south.

XII. *Kaffraria.*

The eastern portion of Cape Colony lying between Natal and the Great Kei River. It is separated from Basutoland on the north-west by the Drakensbergen. The rainfall is abundant everywhere, and excepting near the coast has one maximum and minimum in the year, at about midsummer and midwinter. Going inland up the slopes of the river valleys the mean annual rainfall first diminishes and then increases—again, a circumstance which to some extent reverses the effect due to altitude (see under XV and XVI).

XIII. *Basutoland.*

Rainfall stations only exist in this area along the settled valley of the Caledon River. Nothing is known of the rainfall of the highlands lying between the Maluti and Quathlamba Mountains, which form fully three-quarters of the country; but that the fall is considerable is proved by the numerous streams which form the headwaters of the Orange River. We should conclude from the volume and number of these streams that, if anything, considerably more rain falls upon the western slopes of the mountains of Basutoland than upon the eastern slopes facing the sea. And

this conclusion is confirmed by the testimony of the rain-gauges, so far as they go, Mount Fletcher (XII, 237) and Matatiele (XII, 236) having each a less precipitation than Mozeni (XIII, 253) and Qachas Nek (XIII, 254) across the mountains. Every station in Basutoland has a rainfall of at least 30 in., whereas in Kaffraria only six stations, including St. John's, exceed that round value.

Here, again, the rainfall is of the simple type with a January maximum and July minimum.

XIV. *Orange Free State.*

All Basutoland lying between the western slopes of the Maluti Mountains and the Caledon River belongs to the same geophysical area as the Orange Free State, and stations like Wepener (XIV, 272) and Ladybrand (XIV, 267), near the right bank of the river, have rainfalls similar to those of the left bank in XIII. Going towards the west, however, the conditions become more and more arid, Jacobsdal (XIV, 264) and Philippolis (XIV, 269) having mean annual falls not much greater than that of Kimberley.

Mr. F. S. Lynch, the General Manager of the Kimberley Waterworks Company, has kindly given me the following additional information. His letter is dated October 19, 1915.

Vrede: Average rainfall during the past ten years 26·6 in.

Parys: Average rainfall 21·16 in.

Reitz: Average rainfall approximately 30 in.

Senekal: Average rainfall, 1905 to 1913, 26·68 in.

Bethlehem: Average rainfall during the last ten years 28·824 in.

Heilbron: Average rainfall for past five years 25·45 in.

In each case the information was supplied by the postmaster of the town mentioned.

XV and XVI. *Natal and Zululand.*

Saving the Cape Peninsula this is one of the most interesting rainfall areas in South Africa. It may be divided roughly (and the same division applies also to Kaffraria) into three zones. (1) A zone of heavy precipitation, 40 in. a year and more, along the coast belt; (2) decreasing gradually to a moderate rainfall, 25–30 in., down the centre of the country; and (3) increasing again gradually to upwards of 30 in. under the shadow of the Drakensbergen. Inland there is one maximum near midsummer, and one minimum near midwinter. On the coast there are two maxima, in March and October–November, and two minima, about January and July. According to Mann the rainfall of Natal is caused by two essentially distinct influences: first, by the development in summer of storms more or less of the character of thunderstorms, which most powerfully affect the inland districts and the uplands; and secondly, by the occurrence of sea gales, which fall with most violence upon the coast and the lands in the

close neighbourhood of the sea,* and which come at any season, though perhaps the most pronounced of them have been in the winter. The sea-gale rainfalls are almost invariably associated with a high barometer, while the thunderstorms are as characteristically low-barometer phenomena. Since the winds of Maritzburg, where Mann's observations were taken, are chiefly east to south-east, this observer concluded that Natal must be within the zone of the south-east trade winds, and get its rain from them. Further up the coast, however, in the district of Lourenço Marques, the rainfall becomes less—a fact which does not support Mann's idea. Moreover the same easterly and south-easterly winds blow also in the winter when the interior of Natal is dry.

A typical instance of heavy winter rain occurred on the Natal coast May 31–June 1, 1905, when the following rainfalls were registered in 24 hours—

	Inches.
Umzinto	17·45
Verulam	12·13
Durban	10·70
Maritzburg	4·00
Estcourt	2·05
Utrecht	1·01

showing a progressive decline of intensity as the storm worked inland. It is indeed these sea rains which make up the high mean winter rainfall of the whole eastern coast belt, saving that of Lourenço Marques, from Port Alfred to the tropics.

The following list shows how the annual rainfall varies going from west to east across the Continent, between latitudes 29° and 30° S.:

		Inches.
Port Nolloth	III	2·28
Kraaifontein	,,	5·01
Pella	,,	3·09
Kenhardt	IX	5·50
Prieska	,,	9·74
Griquatown	,,	13·66
Kimberley	,,	17·57
Bloemfontein	XIV	21·94
Thaba 'Nchu	,,	25·13
Ladybrand	,,	30·60
Maritzburg	XV	35·38
Durban	,,	40·54

This gives an annual average increase of rainfall of about one inch for each 22 miles further east. Between Port Nolloth and Kimberley there is

* R. J. Mann, "Contributions to the Meteorology of Natal," 'Quart. Journ. Met. Soc.,' October, 1878.

an extra inch for each 30 miles; between Kimberley and Durban the increase is 1 in. for each 17 miles.

XVII. *Bechuanaland.*

A remarkable feature here is the exceptionally high rainfall of Mafeking. No very obvious explanation of this circumstance is forthcoming; but the rainfall over the greater part of this area is very variable from year to year, floods alternating with long droughts, and Mafeking may have got more than its share of the former. The run of the averages for Palapye Road and Serowe (XVII, 318, 319) is interesting, and not the less so because no particulars of the rainfall of Chief Khama's headquarters have hitherto been published. Another interesting and new station is Tsau, on the northern border of Lake Ngami. Though the record here summarised is a short one, it suggests that some previous assumptions regarding the rainfall round about the Lake were quite wrong.

XVIII. *Damaraland and Great Namaqualand.*

In this interesting region we have desert conditions on the coast belt, with a gradual improvement from west to east and from south to north. To the north-east the general rain conditions are at least as good as those of Griqualand West (compare XVIII and III with IX). A remarkable feature is the rapidity with which the type changes from a winter to a summer rainfall in the vicinity of the Orange River.

XIX–XXIII. *Transvaal.*

This area is not strictly comparable with the others. The mean January, February and March rainfalls for nearly all the stations are artificial, January counting from 1–30, March from 2–31, and February from January 31 to March 1. Few of the stations have much of a record, the exceptions being the mining areas. The fall increases from west to east on the whole. It is high in the north-east highlands, but falls off over the lower levels adjacent to the Portuguese border and Rhodesia. It is mostly thunderstorm rain, with a summer maximum and minimum.

XXIV and XXV. *Southern Rhodesia.*

This area also shows the increase of rain from west to east. It shows also on the whole a heavier summer and a lighter winter rainfall than the Transvaal and Bechuanaland do.

XXVI. *Portuguese East Africa.*

Most of these stations are on the coast. The rainfall varies very much from one year to another, so that the short records cannot possibly give very good averages. Thus while five years of published observations at Beira gave a mean annual rainfall of nearly 51 in., the inclusion of a further

seven years' record, hitherto unpublished, lowered the mean to less than 45 in. Places near latitude 24° S., especially when they project beyond 35° E., have a large winter fall made up apparently of storms similar to those which assail Natal.

XXVII. *British Central Africa.*

A region of abundant mean summer rainfall. Though entirely within the tropics it shows no definite indication of a double annual period. The maximum of intensity, however, appears to come progressively later as we go north, shifting from January to March in eight or nine degrees of latitude. The Nyassa Highlands are the only places where any rain to speak of falls between May and October. Lauderdale (XXVII, 500) appears to be almost the only station in South Africa which lives up to the traveller's wonders of rainfall described in pen and pencil books.

Nearly all the material in XXVII is now published for the first time.

XXVIII. *East Africa.*

The general tendency is to maxima in April, July and November. Inland the July maximum disappears, and the November maximum comes later. The scheme of distribution of the rain over all this area is evidently most complicated, and requires more gauges to the square mile for its elucidation than any other area south of the equator. Aspect nearly everywhere is of more importance than elevation, some of the loftiest stations being among the driest. Compare, *e g.*, Amani with Kwai (XXVIII, 508, 519), Ruteganio (XXVIII, 531) with Fife (XXVII, 495).

XXIX. *British East Africa.*

These particulars have been transcribed from one of the Government reports, and include only recent observations. There appears to be a dry area protruding inland from near the equator and dividing the wet coast from the wet lakes. Thus we have Mombasa (XXIX, 548) with an annual fall of 55·68 in. and Port Florence (XXIX, 555) with 46·60 in.: whereas Kismayu (XXIX, 539) has but 17·08 in., Athi River (XXIX, 536) 25·08 in., and Nakuru (XXIX, 554) 33·24 in.

Various annual mean falls for longer periods than seven years are:

	Years.	Inches.
Mombasa	18	54·43
Fort Hall	10	46·72
Kismayu	15	15·96
Malindi	13	40·01
Makakos	13	35·37
Mumias	11	70·93
Shimoni	14	56·23
Takaungu	12	45·23

3. Notes on the Rainfall Maps.

Some preliminary monthly maps of the rainfall of Cape Colony and the Orange Free State were drawn by Gamble and published in the Report of the Meteorological Commission for 1886. As the observing stations were few in those days, and the records of no great length, there was necessarily a good deal of imagination in the maps, and they only show in a rough way which places are wet and which dry on the whole in given months. Buchan constructed some monthly maps of the rainfall of Cape Colony, the Orange Free State, and parts of Natal and the Transvaal, based upon his discussion of the rainfall of the ten years 1885–94. These were published by the Meteorological Commission in 1897 and were a marked improvement upon Gamble's. They have been reproduced in Bartholomew's 'Physical Atlas,' 1899, and in various other publications. Of the 278 stations for which Buchan had the records, however, only about a half extended to the full ten years, the rest running to anything from three years to nine. Knox, in 1911, published a series of elegant monthly maps of the rainfall of Africa in his 'Climate of the Continent of Africa.' These were based upon odds and ends of scrap-book information culled from all sorts of responsible and irresponsible sources; and consequently the beauty of the maps is no guarantee of their accuracy. Fraunberger and Herbertson have dealt with African rainfall at large. Father Goetz published a detailed map of the annual rainfall of Southern Rhodesia in the Meteorological Report of that Colony for 1908.* C. Stewart prepared a very fine map of the average annual rainfall of the Union of South Africa, and another showing the seasonal distribution of rainfall, for the use of the Select Committee of the Senate on Droughts, Rainfall and Soil Erosion.

The rainfall maps now given are intended to represent graphically the broad features of all the results shown by the rainfall tables. In principle the construction of such maps is easy enough. All we had to do is to draw a series of lines, called "isohyets," each one of which shall pass through all stations having a given rainfall. Thus the isoyhet of 1 in. (equal to about 25 mm.) will join up in a continuous curve all stations in some particular area whose mean annual (or monthly) rainfall is 1 in. In actual practice it is not so easy to draw these lines as it is to state the way to do it. To begin with, very few stations out of the whole number can be found whose annual (or monthly) rainfall is some given quantity. It becomes a question not so much of joining up places having a given rainfall as of drawing an isohyet so that greater falls are on one side of it and lesser falls on the other. Next we have areas in which the rainfall varies very much over very small distances, as in the Cape Peninsula and in mountainous districts here

* See also E. Goetz, "The Rainfall of Rhodesia," 'Proc. Rhodesia Sc. Assoc.,' vol. viii, 1909.

and there; and it is not always easy to determine whether an isohyet should pass round such a place to the right or to the left. Moreover, in areas where there are few gauges the isohyets are usually drawn too simply straight. So that there is always room for bias, and for criticism, upon the details of any rainfall map, whether those before us or any other.

Looking at the annual map, we see that south of latitude 25° S. the isohyets trend mainly north and south, while north of latitude 20° the tendency of the trend is north-west to south-east. A remarkable feature is the dry belt near the tropic of Capricorn, stretching nearly all across the continent, and only broken by the wet oasis of the mountains in the Eastern Transvaal. The course of the isohyets inland from that part of the east coast lying between the parallels of 24° and 27° is to some extent tentative. When more rainfall records are available from the gauges Lieutenant Teixeira is establishing in Portuguese East Africa, it will probably be found that the isohyets meander more than they have been drawn to show.

At first sight it might appear that the small closed isohyet of 60 in. on the tropic, and that of 50 in. near latitude 27°, ought to be in more intimate communication with one another, and one feels tempted at first to run the isohyet of 30 in. inland from about the place where the parallel of 27° meets the coast, and below the 50-in. isohyet rather than above it. The intrusion of the isohyet of 20 in. from the west, nevertheless, in the immediate neighbourhood, as well as the dry belt pushing westwards from Lourenço Marques, support the map.

It is curious how relatively few conspicuous instances there are in which the mountain ranges show a pronounced influence upon the rainfall. It is evident that the distribution of South African rainfall is of general significance, and that local conditions are quite a secondary matter. Local influence can be traced along the terraces facing the Atlantic, along the Langebergen and Outniquas, in the Amatolas, in the northern end of the Drakensbergen, and, perhaps most strikingly of all, in the Zoutpansbergen, which, as we have seen, is the one obstacle to the uninterrupted course of the tropical dry belt across the continent. Lake Nyassa is an oddity: the Shire Highlands manage to catch the rain; but if the map is to be trusted, the western side of the lake is much wetter than the eastern side in spite of the Livingstone Range.

The most likely explanation of the lack of concordance between the distribution of rainfall and the physical features of the land is that most South African rain falls in thunderstorms, whose origins and tracks are largely independent of the geographical contours, and whose clouds are higher than most of the mountains. Now it is the almost universal custom to fill up by inference the gaps in our actual knowledge of the rainfall, and this usually resolves itself into an effort to make the isohyets and the land contours coincide. Thus if we have a semicircular range of hills with only

two rain-gauges, one at each extremity, and the mean rainfall at the two gauges is about the same, say 20 in., then in nine cases out of ten such the isohyet of 20 in. would be drawn with a semicircular sweep to follow the course of the hills, and in eight cases of the nine the isohyet might prove to be nearly correct. Such a plan has been followed to some extent here; but the facts as we find them show that in the lump inference is a poor substitute for knowledge, and that no such success in guessing can be expected in South Africa as is attained in countries where thunderstorms are fewer. Indeed, even in England, where the mean isohyets are almost entirely of geographical inception, Mill has discovered that *heavy* rain, whether it fall in thunderstorms or during cyclonic disturbances, falls impartially on high or on low ground without any regard to the configuration of the country. "It seems," says Mill, "that the causes determining the fall of rain on these occasions are to be sought in the air alone, and that at a level so far above the surface that inequalities of ground, even amounting to several thousand feet, are without direct influence upon them."* We may understand from this the great want of concordance between the isohyets and the contour of South Africa. If we would discover the reason why our isohyets bend this way or that, we must first discover the reason why thunderstorms form and travel as they do.

The same sort of considerations apply to the monthly maps. If we study them carefully, in order, month by month, we begin to see that the monthly mean rainfall over any area taken at random is not dependent so much upon the impinging of moisture-laden winds from the ocean upon lofty slopes, as upon the more general progressive movements of a rainfall belt to and from the equator.

Consider, *e. g.*, the isohyet of 8 in. In January this bends inland near latitude 17°, follows the course of the Zambesi to near longitude 25°, turns northwards to latitude 10°, crosses and recrosses this parallel, and finally runs down the meridian of 40° to the sea. Over all the land within this line the mean January rainfall exceeds 8 in. In February we find the area enclosed by the same isohyet somewhat further south, its southern boundary crossing the Zambesi and reaching the coast below Beira. In March it has retreated northwards again, its northern boundary being near latitude 8°, its southern boundary about 14°. In April it has nearly disappeared from the map and does not reappear until December.

In January the 4-in. isohyet meanders from west to east between the 7th and 30th meridians above and below the parallel of 21°; it then turns towards the south-west as far as latitude 27°, from whence it wanders south-east to the sea. To the left of this line the rainfall is greater than 4 in.; to the right it is less, and it gradually tails off to nearly nothing

* H. R. Mill, "Map-studies of Rainfall," 'Quarterly Journ. R. Met. Soc.,' April, 1908.

along the lower half of the west coast. In February the same isohyet has shifted a little south; in March it has edged off to the north-east, while in April it is shown running nearly due west to east along the parallel of 11°. It is not drawn on the December map, but its course can be mentally followed between the isohyets of 3 and 5 in., and from these we see that it is pretty much the same as it is in March.

In January the 1-in. isohyet runs south from near the top left-hand corner of the map to latitude 25°, where it curves more to the east. In February it is rather nearer the Atlantic, and in March still nearer—albeit the 2-in. isohyet in this month has pushed out a long tongue eastwards. In April it has moved considerably northwards, and embraces the whole of the interior. In May it has retreated to the equator. In October it begins to show again north of the 15th parallel; and can be followed in November and December closing down upon its first position near the west coast.

Of the other isohyets much the same may be said. In fact they form together one system which moves north and south as the sun moves, but with a lag of a month or more. That is, in September, when the sun is on the equator, going south, the zone of heaviest rainfall is in the northern hemisphere, and it does not reach the equator for upwards of a month; in March, when the sun is again on the equator, going north, the zone of heaviest rainfall extends along the parallel of about 10° S. This is not to say that the rainfall system retains a uniform aspect as it swings north and south. At one time the isohyets may be closing up together; at another they may be opening out. The isohyets of 1 and 2 in., *e.g.*, are further apart in November than they are in January.

The zero isohyet is interesting. In June it occupies a considerable belt of the country lying between latitudes 5° and 18°. In July it circuits a much larger area, having extended outwards north and south; but its southward progress has evidently received a check in the high land near the tropic, facing the Atlantic—an indication that occasional though trivial rain falls at this place in July. And, curiously enough, as the area within the zero isohyet comes still further south we see that these reluctant rains invade it for a considerable distance from the south, reducing the area of no rain, in August, by many thousand square miles, and nearly obliterating it altogether in September.

Corresponding to the general movements of the main isohyetal system are the movements of the subsidiary systems found on the coast—the winter rains of the south-west, for example, which advance as the summer rains retreat, and *vice versâ*, and the rains of the south and south-east coastal belt. The winter rains of the south-west do, indeed, now and then, and the southern coastal belt rains not infrequently, push their way inland as far as Kimberley and Bloemfontein.

4. Some Details of Rainfall.

Table A.—*Mean Hourly Variation of Rainfall at Kenilworth.*

Hour (ending).	Frequency (times).	Quantity (inches).	Rate (inches).
I	13	·64	·049
II	12	·55	·046
III	11	·61	·055
IV	10	·48	·048
V	11	·47	·043
VI	11	·43	·039
VII	9	·34	·038
VIII	10	·34	·034
IX	9	·31	·034
X	8	·26	·033
XI	8	·27	·034
Noon	8	·33	·041
XIII	10	·50	·050
XIV	15	1·11	·074
XV	18	1·05	·056
XVI	19	1·15	·061
XVII	19	1·52	·080
XVIII	19	1·27	·067
XIX	18	·94	·052
XX	18	1·05	·058
XXI	18	1·01	·056
XXII	16	·78	·049
XXIII	15	·69	·046
Midnight	14	·78	·056
Year	319	16·88	·053

Table A shows how the rate of rainfall varies from hour to hour at Kenilworth (Kimberley). It is deduced from observations made during the 17 years 1897 to 1913—a period in which the annual average fall was an inch or so less than the normal mean used in IX, 178 of the rainfall table

The numbers under the heading "Frequency" tell how many times on an average it was raining during each given hour throughout the year. Thus for the hour ending 1 a.m. there was, on an average, rain on 13 days of the year; for the hour ending 4 p.m. there was rain on 19 days; and so on. Upon the whole there were 319 hours per annum during which rain was recorded, *i.e.* less than one hour a day. Since the average number of rainy days at Kenilworth is about 70, it follows that an average wet day would run to about 4½ hours of rainfall.

TABLE B.—*Miscellaneous Details of Rainfall.*

Section.	Average number of rainy days per annum.	Greatest rainfall in one year. (inches).	Heavy rainfall in 24 hours.
I	152	126·18	6·00 at Newlands.
II	110	115·47	5·93 ,, Berg River.
III	75	34·60	3·14 ,, Dassen Island.
IV	138	69·27	16·50 ,, Swellendam.
V	59	28·12	4·63 ,, Kleinpoort.
VI	51	47·26	5·00 ,, Zwartberg Pass.
VII	92	44·17	4·60 ,, Somerset East.
VIII	70	34·81	4·30 ,, Petrusville.
IX	70	38·47	4·60 ,, Campbell.
X	152	103·11	11·33 ,, Evelyn Valley.
XI	101	56·53	5·94 ,, Ellesmere.
XII	130	68·54	9·29 ,, Flagstaff.
XIII	96	49·19	4·25 ,, Mafeteng.
XIV	—	43·29	—
XV	162	73·00	17·45 ,, Umzinto.
XVII	60	28·44	5·20 ,, Vryburg.
XIX to XXIII	86	—	4·09 ,, Pretoria.
XXIV	77	45·30	5·45 ,, Gwels.
XXV	100	72·15	—
XXVII	123	—	—

The average precipitation for each hour is given under the heading "Quantity." The driest hour of the day is 9 to 10 a.m. with scarcely more than a quarter of an inch a year; the wettest hour is 4 to 5 p.m. with six times as much. The hourly quantities are somewhat irregular, probably because 17 years is too short a period to produce a smooth curve.

The numbers under the heading "Rate" specify the average hourly intensity of rainfall. It is deduced by dividing the whole fall per hour per annum by the number of hours it took to fall in, or—

Quantity / frequency = rate.

We see that the hourly average rate of rainfall in wet weather rises and falls as the hourly average frequency increases and diminishes—that is to say, the hour which carries the greatest chance of rain carries the heavier fall when it comes. The lightest rain comes between 7 and 11 a.m., the heaviest in the afternoon.

In Table B some miscellaneous details of rainfall are given, taken mainly from the records of the twelve years 1897 to 1908. The "Average number of rainy days" does not, excepting in a few instances, apply to any one station in a particular section, but is really the average of the greatest

number of rainy days reported, from whatever station in the section, each year. For Section IX the number of rainy days at Kenilworth is used; for XV those of Durban; XIX to XXIII takes Pretoria and Johannesburg; XXIV is for Bulawayo; XXV is for Melsetter; and XXVII is for Zomba. Altogether the section with the greater rainfall has the greater number of rainy days.

A "rainy day" is a day upon which the precipitation is at least ·01 in.

The hour at which the rainy day is supposed to end has a curious influence on the number of rainy days in a year. Thus at Kenilworth it makes all the difference whether the day is reckoned from 8 a.m. to 8 a.m., or from 8 p.m. to 8 p.m. In the former case the average number of rainy days for the 14 years 1901 to 1914 is 70, whereas in the latter case the average number is 75. The reason for the difference is that it rains more often (see Table A) at 8 p.m. than it does at 8 a.m. Suppose it to be raining from 7 to 9 p.m. on June 10, and the hourly fall to be

7–8 p.m. . .	·15 in.
8–9 p.m. . .	·12 in.

This would give us one day's rain of ·27 in. for the 24 hours ending 8 a.m. June 11, but one day's rain of ·15 in. for the 24 hours ending 8 p.m. June 10, and another of ·12 in. for the following 24 hours.

In addition to 75 days (8 p.m. to 8 p.m.) of rainfall in measurable quantities at Kenilworth in a year, there are 25 more days upon each of which only a few drops are noted.

The "Greatest rainfall in one year" (Table B) applies to any station in a given section. Mostly the wettest years occur at places where the mean rainfall is the greatest.

The last column of Table B gives some typical heavy rainfalls in 24 hours. The quantity shown for Section IV is remarkable. Previous to 1906 the average rainfall for December at Swellendam was 2·36, derived from 25 years of observation. In December, 1906, there were torrents of rain ("cloudbursts" in the vernacular) experienced over nearly the whole of Section IV, and probably the most intense ever known there. In that month 26·72 in. fell at Swellendam and 16·32 in. at Heidelberg, of which 65·01 in. fell in one day at the former place and 11·37 in. at the latter.

5. A Note on South African Hailstorms.

A good deal of the South African rainfall occurs in hailstorms.

Lenard has found that raindrops exceeding 0·1 in. radius cannot last, but break up into smaller fragments in a very few seconds, while tiny drops can hold themselves intact in strong tumultuous gusts of wind. Hailstones, however, can go on growing even to the size of cricket balls. Some of the

stones which fell at Maritzburg in April, 1874, were too big to go into a breakfast cup, measured $4\frac{1}{2}$ in. in one diameter and $3\frac{1}{2}$ in. in the other and weighed up to $1\frac{1}{2}$ lb. avoirdupois.* These stones, therefore, were a matter of 65,000 times as large as the largest possible raindrop; their terminal velocity must have been very much greater than that of any raindrop, so that it is no wonder that they crashed through corrugated iron roofs as they would through paper.

Two newspaper accounts of heavy South African hailstorms are given below:

(1) From the *Diamond Fields Advertiser* of December 12, 1915:

"*Weather Extraordinary: Remarkable Wind and Hail.*—The *Mafeking Mail* on Monday had a report of an extraordinary storm stated to have occurred in the vicinity of Hildavale a few days previously. The full fury of the storm, it was stated, was felt on the farm Raailies Park, while other farms in the neighbourhood to suffer included those of Messrs. Odendaal Van Wijk (De Rust), Adams (Thorn Park), and Greenberg (Crowsley Park). Mr. Durand was reported as having stated that the storm pursued a narrow path about 350 yards wide, and for a distance of a mile every tree and shrub in its course was destroyed. Of the trees many were twisted off at the trunk but the majority were torn out of the ground. Examination of this devastated belt afterwards showed that many of the larger trees were carried away for some 20 yards with their trunks trailing on the ground, and were then lifted clear of the ground and deposited many yards distant. A further and perhaps more telling illustration of the fury of the tornado may be found in the fact that 350 yards of fencing in its path was wholly destroyed—not only were the iron standards twisted in corkscrew fashion and bent, but the strands of wire were broken in many places, doubtless due to the uprooted trees being hurled against them.

"There followed a hailstorm of exceptional violence. Says the paper named: 'For nearly five minutes great isolated chunks of ice fell. We have the authority of Mr. Durand for stating that four of these chunks, weighed collectively, turned the scale at 4 lb., and the measurements of one were: width 4 in., depth 4 in., and length $4\frac{1}{2}$ in. Numerous hail-stones weighing over $\frac{3}{4}$ lb. also fell. Into ploughed land the bigger stones penetrated to a depth of from 2 to 3 in. and it would be better to imagine than experience a bombardment with such missiles had such been accompanied by a heavy wind.

"'As it was, Mr. Durand's losses in livestock were considerable. Of one flock of sheep 14 were killed outright and 16 died later, while 30 or 40, though very badly bruised and bleeding, are recovering. An ox had its eye

* Natal. 'Commission appointed to Enquire and Report upon the Extent and Condition of Forest Lands in the Colony,' 1880. Also, Rev. J. D. la Touche in 'Quart. Journ., R. Met. Soc.,' October, 1874.

destroyed, while a two-year-old heifer belonging to Mr. Du Plessis was killed.

"'Packing cases outside Mr. Durand's homestead were smashed to matchwood. The thatch on two rooms adjoining the homestead was completely demolished, a circumstance which rendered the rooms altogether untenable, while at Mr. Odendaal's homestead one hailstone crashed clean through the verandah roof—of corrugated iron—leaving a hole of about 3 in. in diameter. At the end of five minutes smaller hailstones fell, and continued for some ten minutes. No great quantity of rain fell—in fact just before the water began to "run" on the veldt the storm ceased.'

"Apparently the foregoing details were received with incredulity by the readers of the paper, which on the following day printed a confirmatory letter from the owner of Thorn Park—Mr. A. E. Adams, who wrote:

"'On Wednesday we experienced a terrible hailstorm, the like of which I had never before seen. I have often heard of hailstones the size of turkey-eggs, but have not seen them, but some of those that fell on Wednesday afternoon were larger than goose-eggs. The majority were the size of tennis balls. The circumference of one I measured was 13¾ in. one way and 9¾ in. the other, and many weighed just over a pound. Luckily no wind accompanied the hail. I had three sheep killed, while a number had one or more legs broken and their eyes knocked out. Mr. Durand lost 30 sheep, and Mr. Du Plessis a cow.

"'My garden was knocked to atoms; scarcely anything is left. Galvanised iron was dented all over, and a few holes were knocked in the iron. Any number of springbok and stembok were killed over on the flats.'"

(2) From the same paper of January 3, 1916:

"Mr. J. Allen, of Kildavale, Rhodesia, writes to the Bedford paper as follows: On December 15 we had an exceptionally heavy hailstorm here, in which the hailstones were the largest ever seen by inhabitants of this part of the country. On this farm they were as large as tennis balls. We measured four of them, the largest being 13¼ in. in circumference, and weighing little over, half a pound, and the remaining three measuring between 10 and 12 in. A neighbour, however, seems to have beaten this, one measuring 18 in. in circumference and weighing a pound. The storm lasted about ten minutes, the hail being small at first, and increasing in size. Luckily the storm was not accompanied by wind, otherwise the losses would have been much greater. As it is, one farmer lost 28 sheep killed, and many with legs broken and minus eyes. The cattle had large lumps on their bodies, some also losing eyes. Many holes in the ground caused by the stones were from 1 to 2 in. deep. Old natives born here say they have not seen hailstones as large as these."

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Table of Monthly Mean Rainfall.

I.—*Cape Peninsula.*

	Ref No	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Bishop's Court	1	33° 58′	18° 27′	250	29	1·45	·82	1·76	4·43	8·43	10·31	8·19	8·51	5·58	4·61	1·97	1·80	57·90
Blaauwberg Strand	2	33 47	18 28	10	14	·64	·21	·51	1·26	2·05	2·16	1·68	2·03	1·22	1·15	·79	·44	13·94
Cape Point	3	34 21	18 30	730	9	·42	·38	·44	1·55	1·73	2·15	1·21	1·22	1·20	1·37	·45	·57	12·70
Devil's Peak:																		
Lower Gauge	4	33 57	18 27	1050	13	1·71	·98	1·64	3·68	6·57	8·21	6·72	5·72	4·32	2·88	1·82	1·77	47·02
Nursery	5	33 57	18 27	1200	13	2·05	1·02	1·93	4·04	7·25	9·06	7·48	6·32	4·77	4·33	2·04	2·04	52·32
Blockhouse	6	33 57	18 27	1500	13	2·35	1·17	2·13	4·51	8·10	10·33	8·22	7·23	5·15	4·85	2·35	2·27	58·67
Molteno Reservoir	7	33 56	18 24	206	21	·98	·57	1·08	3·03	4·90	5·73	4·72	3·98	2·80	2·26	1·28	1·20	32·53
Platteklip	8	33 57	18 25	550	27	1·34	·97	1·70	3·92	6·46	7·72	6·61	5·59	4·14	3·28	1·86	1·75	45·34
Robben Island	9	33 48	18 23	25	15	·66	·27	·55	1·59	2·46	3·18	2·30	2·71	1·72	1·34	·77	·59	18·14
Rondebosch	10	33 58	18 29	100	22	1·18	·79	1·41	3·31	6·37	7·00	6·83	6·18	3·54	2·84	1·67	1·44	42·56
Royal Observatory	11	33 56	18 29	30	73	·70	·59	·96	2·00	3·99	4·45	3·55	3·44	2·29	1·74	1·19	·86	25·63
Sea Point	12	33 56	18 23	15	23	·71	·45	·66	2·12	3·29	3·87	2·77	2·66	2·15	1·60	·77	·77	21·82
Signal Hill	13	33 55	18 24	1143	26	·49	·38	·65	1·75	2·87	3·03	2·41	2·34	1·82	1·37	·76	·65	18·52
Simonstown	14	34 12	18 26	12	28	1·01	·85	1·38	2·71	4·47	5·07	4·22	4·04	3·00	2·60	1·48	1·17	32·00
Table Mountain:																		
Disa Head	15	33 59	18 24	2496	27	1·20	1·22	1·76	3·86	5·41	6·11	5·32	4·61	3·52	3·27	2·06	1·78	40·11
Kasteel Poort	16	33 59	18 24	2500	24	2·06	1·70	2·71	5·03	8·55	10·48	8·50	7·64	5·32	5·05	2·94	2·45	62·43
St. Michael's	17	33 58	18 25	3050	24	2·53	2·29	3·26	5·94	10·36	12·73	10·34	9·36	6·21	6·06	3·69	3·19	75·96
Waai Kopje	18	33 58	18 25	3100	27	2·27	1·93	2·95	5·41	9·44	10·65	8·85	8·12	5·79	5·32	3·33	3·07	67·12
Wynberg	19	34 0	18 28	235	29	1·09	·63	1·40	3·19	6·69	7·98	6·10	6·58	4·49	3·43	1·32	1·28	44·49
			Means			1·31	·91	1·52	3·33	5·76	6·85	5·60	5·17	3·63	3·18	1·70	1·53	40·48
Additional Stations.																		
Table Mountain:																		
Dam	14a	—	—	2413	18	2·49	1·48	3·24	4·87	7·50	10·09	8·39	8·07	5·88	5·36	3·22	3·78	64·37
Maclear's Beacon	16a	—	—	3586	19	3·16	1·85	3·73	6·67	10·17	14·60	12·77	12·72	8·57	7·34	4·06	3·66	89·30
Waai Vlei	18a	—	—	2900	19	2·63	1·62	3·40	5·88	8·26	11·68	9·74	10·01	6·99	6·07	3·27	3·22	72·77

II.—*South-Western Cape Province.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Caledon	20	34° 13′	19° 25′	760	29	·90	·81	1·23	1·98	2·39	2·41	2·10	2·56	1·93	2·06	1·17	1·02	20·56
Ceres	21	33 22	19 19	1493	29	1·20	·53	1·12	3·33	6·55	6·38	4·95	5·97	4·30	3·54	1·66	1·36	40·89
Danger Point	22	34 37	19 18	64	8	1·07	·79	1·38	2·10	3·56	4·26	2·27	3·56	2·80	2·77	1·21	1·23	27·00
Eerste River	23	34 2	18 44	100	16	·86	·38	·77	1·97	2·97	3·60	2·55	3·62	2·26	1·81	·82	·85	22·46
Hex River	24	33 29	19 26	—	10	·57	·48	·84	1·66	1·92	1·80	1·71	2·54	1·43	1·02	·54	·56	15·07
Houw Hoek	25	34 12	19 10	960	14	·88	·65	1·38	2·36	3·03	2·83	3·06	2·89	2·27	1·93	1·01	·72	23·01
Karnmelk's River	26	34 22	19 42	600	10	·81	·88	1·27	1·73	2·46	2·39	1·93	2·74	1·88	2·57	1·16	1·08	20·90
Klapmuts	27	33 48	18 51	555	25	·97	·53	1·09	2·66	4·40	4·80	3·73	4·10	2·79	2·39	1·26	·74	29·46
Kluitjes Kraal	28	33 26	19 11	880	16	·77	·47	·79	2·70	3·63	3·89	2·99	3·70	2·34	2·13	1·17	·60	25·18
Montagu	29	33 48	20 8	727	25	·51	·69	·60	1·43	1·68	1·34	1·20	1·44	1·40	1·03	·75	·58	12·65
Paarl	30	33 45	18 57	500	29	·88	·58	1·03	3·05	4·96	5·88	4·26	5·24	3·05	2·34	1·16	·84	33·27
Robertson	31	33 47	19 53	600	29	·56	·91	·79	1·36	1·27	1·31	1·15	1·20	1·27	1·12	·77	·78	12·52
Rocklands	32	33 6	19 20	2500	18	·56	·40	·62	2·10	4·24	3·34	2·90	3·19	2·50	1·67	·82	·79	23·13
Somerset West	33	34 5	18 51	100	26	·87	·48	1·03	2·12	3·89	4·10	2·93	3·40	2·35	2·10	·93	·65	24·86
Stellenbosch	34	33 56	18 51	400	29	·76	·62	·96	2·45	4·34	4·33	3·51	3·92	2·75	2·25	1·21	·88	27·98
Tulbagh	35	33 18	19 8	490	29	·53	·55	·69	1·82	2·78	2·44	1·95	2·39	2·11	1·59	·84	·64	18·23
Wellington	36	33 38	18 59	400	29	·89	·65	·89	2·53	3·89	4·49	3·10	3·56	2·48	2·06	·81	·72	26·07
Weltevreden	37	33 52	19 1	540	16	1·33	·62	1·28	3·15	5·15	6·29	4·48	4·95	2·96	3·06	1·33	·76	35·37
Worcester	38	33 39	19 26	780	29	·36	·35	·52	1·18	1·41	1·60	1·23	1·51	1·28	1·06	·42	·50	11·43
			Means			·80	·59	·96	2·19	3·40	3·55	2·74	3·29	2·32	2·03	1·00	81	23·69

III.—*Western Cape Province.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
A. NAMAQUALAND.				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Anenous	39	29° 15′	17° 34′	1774	9	·09	·11	·14	·45	·64	·63	·58	·60	·67	·42	·31	·19	4·83
Garies	40	30 33	18 0	830	19	·06	·06	·10	·65	·72	·64	·75	·70	·46	·33	·22	·16	4·85
Keerom	41	29 58	17 38	1500	4	·05	·68	·19	·39	·52	1·95	1·23	1·00	·61	1·18	·17	·13	8·10
Klipfontein	42	29 12	17 39	3104	23	·15	·33	·36	·83	1·28	·88	·83	1·06	·68	·58	·31	·18	7·47
Kraaifontein	43	29 15	17 44	2700	17	·14	·22	·26	·56	·77	·61	·63	·74	·46	·36	·18	·08	5·01
Lilyfontein	44	30 18	18 5	5000	15	·33	·46	·40	1·25	1·89	1·69	1·51	1·67	1·14	1·09	·59	·39	12·37
O'okiep	45	29 36	17 52	3036	26	·17	·33	·42	·82	1·07	·91	·72	·81	·72	·54	·21	·17	6·89
Pella	46	29 2	19 9	1800	29	·24	·41	·64	·35	·20	·11	·06	·15	·17	·47	·12	·17	3·09
Port Nolloth	47	29 15	16 52	40	27	·04	·05	·12	·27	·46	·29	·28	·30	·18	·12	·10	·07	2·28
Springbok	48	29 40	17 53	3200	29	·18	·34	·56	·76	1·29	1·18	·92	1·09	·90	·69	·28	·19	8·38
			Means			·15	·30	·32	·63	·88	·89	·75	·81	·60	·58	·25	·17	6·33
B. SOUTHERN SECTION.																		
Clanwilliam	49	32° 10′	18° 53′	245	29	·23	·28	·28	·82	1·38	1·33	·97	1·00	·89	·62	·33	·18	8·32
Dassen Island	50	33 24	18 6	15	15	·76	·19	·38	1·26	2·18	2·26	1·64	2·08	1·35	·90	·46	·29	13·75
Ebenezer	51	31 35	18 20	100	7	·02	·04	·24	86	·57	·49	·54	·56	·82	·21	·15	·14	4·64
Groote Post	52	33 28	18 24	—	17	·41	·52	·52	1·30	3·02	3·28	2·81	2·40	1·61	1·34	·79	·67	18·69
Hopefield	53	33 4	18 21	250	11	·66	·20	·43	1·28	1·72	2·12	1·73	2·24	1·25	·96	·45	·33	13·37
Kersefontein	54	32 53	18 21	15	17	·35	·14	·38	1·19	1·74	2·14	1·71	1·92	1·17	·90	·42	·28	12·35
Malmesbury	55	33 28	18 43	460	29	·49	·41	·63	1·78	2·75	2·74	2·11	2·47	1·87	1·38	·72	·49	17·84
Piquetberg	56	32 54	18 43	700	29	·57	54	·58	1·72	3·11	2·87	2·55	2·62	2·32	1·89	·91	·69	20·37
Saron	57	33 11	19 0	600	14	·51	·57	·65	2·10	4·41	3·65	2·89	2·91	2·91	2·15	·83	·63	24·21
The Towers	58	33 25	18 28	—	17	·73	·24	·55	1·71	2·75	2·96	2·54	3·02	1·74	1·32	·71	·46	18·72
Van Rhyns Dorp	59	31 35	18 44	400	22	·08	·19	·16	·87	1·00	·87	·75	·70	·54	·40	·17	·11	5·84
Wupperthal	60	32 15	19 13	—	17	·27	·42	·33	1·31	1·57	1·73	1·02	1·45	·84	·68	·40	·30	10·32
			Means			·42	·31	·43	1·35	2·18	2·20	1·77	1·95	1·44	1·06	·53	·38	14·03

IV.—*Southern Cape Province.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
A. West.				Ft.		In	In	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Bredasdorp	61	34° 33′	20° 2′	250	29	90	1·34	1·61	1·77	2·04	1·94	1·83	2·25	1·65	2·03	1·36	1·14	19·85
Cape Agulhas	62	34 50	20 1	55	27	·76	·60	1·17	1·64	2·15	2·32	1·88	1·89	1·37	1·46	·75	·79	16·78
Dumbiedykes	63	34 4	22 5	67	23	·92	1·84	1·43	2·00	1·39	1·02	·74	1·07	1·96	1·73	1·47	1·29	16·86
George	64	33 57	22 29	620	29	2·91	3·48	3·39	2·85	2·63	2·20	1·47	2·52	3·36	3·48	3·02	2·96	34·28
Heidelberg	65	34 5	20 58	100	28	1·00	1·60	1·61	1·87	1·73	1·30	·98	1·40	1·60	1·91	1·29	1·49	17·78
Millwood	66	33 50	22 50	1500	21	3·52	4·05	4·35	3·11	2·78	2·78	1·51	2·72	4·19	4·55	4·12	3·76	41·44
Mossel Bay	67	34 11	22 9	105	27	·95	1·44	1·47	2·07	1·72	1·25	1·15	1·37	1·81	1·69	1·19	1·44	17·55
Riversdale	68	34 6	21 16	100	29	1·05	1·29	1·65	1·99	1·53	1·30	1·07	1·29	1·57	1·66	1·39	1·40	17·20
Sour Flats	69	33 57	23 0	710	20	3·04	3·66	3·19	2·84	2·41	2·50	1·66	2·63	3·82	3·68	3·40	3·14	35·01
Swellendam	70	34 4	20 27	500	28	2·39	2·73	3·04	3·08	3·11	2·16	2·04	2·49	2·84	3·41	2·55	3·26	33·11
Means						1·74	2·20	2·29	2·32	2·15	1·88	1·43	1·96	2·42	2·56	2·05	2·07	25·09
B. East.																		
Buffels Nek	71	33° 53′	23° 10′	2200	18	3·98	4·48	4·48	3·69	3·25	3·93	2·26	3·50	5·59	5·12	4·52	4·29	49·09
Cape St. Francis	72	34 12	24 50	20	28	1·29	·93	2·13	2·50	3·04	2·50	2·56	3·23	2·49	2·86	2·07	1·91	27·52
Dunbrody	73	33 30	25 28	200	22	1·14	1·15	1·81	1·54	1·10	·82	·57	·82	1·46	1·49	1·76	1·83	15·58
Humansdorp	74	34 2	24 46	360	27	1·66	1·69	2·47	2·24	2·43	2·01	1·87	2·79	2·25	2·62	2·70	1·99	26·72
Knysna	75	34 3	23 3	30	28	2·03	2·11	2·54	2·33	2·35	2·25	2·26	2·50	2·91	2·79	2·31	2·39	28·75
Plettenberg Bay	76	34 4	23 22	240	17	1·81	2·02	2·04	2·29	2·51	2·33	2·04	2·23	3·13	2·68	1·83	2·34	27·24
Port Elizabeth	77	33 58	25 37	181	29	1·04	·92	1·62	1·96	2·30	1·54	1·60	2·16	2·16	2·00	2·13	1·72	21·15
Storms River	78	33 58	23 52	580	25	3·51	3·48	3·93	3·60	3·60	2·76	2·68	3·74	4·69	4·69	3·77	4·01	44·47
Tankatara	79	33 41	25 42	100	27	·90	1·26	1·70	1·51	1·27	1·31	·74	1·33	1·72	1·59	1·98	1·76	17·07
Uitenhage	80	33 47	25 24	190	29	·86	1·29	1·95	1·64	1·32	·94	·66	1·43	1·72	1·63	2·05	1·60	17·09
Van Staadens Reservoir	81	33 52	25 16	1522	28	2·05	2·15	2·53	2·57	2·44	1·77	1·91	2·70	3·35	3·31	2·91	2·56	30·24
Walmer Heights	82	33 59	25 36	450	25	1·81	1·62	2·43	2·62	3·14	2·06	2·25	3·11	2·90	3·12	3·23	2·81	31·10
Means						1·84	1·92	2·47	2·37	2·40	2·02	1·78	2·46	2·86	2·83	2·61	2·43	28·00

V.—*Southern Karroo.*

	Ref. No.	S. lat.	E. long.	Alt.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
A. WEST.				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Amalienstein	83	33° 29′	21° 29′	1570	29	·92	1·24	1·39	1·35	1·13	·81	·70	·84	1·13	1·41	·87	·95	12·74
Calitzdorp	84	33 32	21 41	750	29	·63	·98	1·12	·99	·58	·41	·29	·50	·85	·88	·60	·70	8·52
Ladismith	85	33 29	21 17	1860	28	1·11	1·28	1·52	1·65	1·18	·92	·79	·98	1·24	1·30	·84	·91	13·71
Oudtshoorn	86	33 35	22 13	1090	28	·55	·80	1·02	·92	·99	·75	·47	·89	1·09	·93	·59	·49	9·48
Pietermeintjes	87	33 15	20 30	3595	9	·51	·42	·84	1·54	1·16	1·30	1·03	1·36	·75	1·09	32	·62	10·94
Touw's River	88	33 20	20 3	2500	27	·44	·47	·74	1·03	1·09	1·24	·99	·89	·77	·61	·33	·27	8·87
Triangle	89	33 26	19 49	3155	9	·47	·86	·58	1·49	1·06	1·23	·76	1·18	·59	·75	·20	·41	9·58
			Means			·66	·86	1·03	1·28	1·03	·95	·72	·95	·91	·99	·54	·62	10·55
B. EAST.																		
Glenconnor	90	33° 24′	25° 10′	730	24	1·22	·89	1·57	1·04	·83	·60	·28	·69	1·46	1·13	1·54	1·30	12·56
Kleinport	91	33 20	24 53	1900	27	1·00	1·00	2·07	1·17	·70	·50	·28	·61	1·36	1·31	1·09	1·26	12·34
Uniondale	92	33 29	23 9	2240	29	·71	1·01	1·43	1·26	1·39	1·17	·96	1·33	1·44	1·20	1·09	·72	13·71
Vlakte Plaats	93	33 30	22 42	1800	12	·82	·98	1·24	·59	1·03	·81	·83	·59	·75	·80	·98	·47	9·89
			Means			·94	·97	1·58	1·02	·99	·77	·59	·80	1·25	1·11	1·17	·94	12·13

VI.—*West-Central Karroo.*

	Ref. No	S. lat.	E. long.	Alt.	Years.	Jan.	Feb	Mar.	Apr.	May.	June.	July	Aug.	Sept	Oct.	Nov	Dec	Year
A. WEST.				Ft.		In.	In.	In	In.	In	In.	In	In	In.	In	In	In	In.
Beaufort West .	94	32° 21′	22° 34′	2850	29	1·03	1·06	1·35	·77	·64	·27	·23	·31	·70	·69	·80	·95	8·81
Dunedin .	95	32 3	22 35	4000	16	·75	1·03	1·13	·81	·66	·27	·35	·22	·35	·52	·58	·48	7·15
Fraserburg Road	96	32 40	22 0	1820	25	·57	·61	·81	·68	·45	·21	·07	·21	·26	52	·50	·45	5·34
Grootfontein	97	33 7	21 17	2405	9	·37	·57	·71	·76	·37	·13	·17	·27	·27	·67	·13	·31	4·73
Matjesfontein	98	33 14	20 36	2970	25	·32	·43	·60	·86	·70	·76	·46	·54	·55	·62	·20	·32	6·36
Prince Albert .	99	33 11	22 2	2120	29	·48	·72	1·19	·98	1·12	·65	·22	·52	·71	·71	·50	·57	8·36
Prince Albert Road	100	32 58	21 43	2020	25	·40	·45	·73	·43	·37	·27	·09	·18	·39	·51	·37	·33	4·52
Zwartberg Pass	101	33 21	22 34	5200	19	2·10	2·02	2·34	2·66	1·92	2·22	1·29	1·79	3·41	3·14	2·28	2·24	27·41
			Means .		.	·75	·86	1·11	·99	·78	·60	·36	·50	·83	·92	·67	·71	9·08
B. EAST.																		
Baakens Rug	102	32° 18′	23° 16′	3750	19	1·38	·95	1·49	·92	·63	·32	·26	·26	·73	·60	·77	·97	9·28
Camfers Kraal	103	32 14	23 3	3012	29	1·14	1·03	1·59	·89	·58	·22	·15	·21	·56	·52	·66	·79	8·34
Nelspoort .	104	32 9	23 1	3125	19	1·41	1·22	1·73	·84	·60	·29	·25	·23	·74	·74	·86	·97	9·88
Lower Nelspoort	105	32 11	23 4	3100	25	1·41	1·25	1·84	·90	·66	·33	·29	·30	·57	·51	·92	·96	9·94
Rietfontein	106	32 59	23 49	2271	40	1·00	1·39	1·63	·90	·78	·41	·31	·51	·68	·98	94	·98	10·51
Steytlerville	107	33 20	24 19	—	16	·80	1·10	1·64	·74	·47	·31	·16	·53	·84	·86	·77	1·00	9·21
Willowmore	108	33 17	23 20	2760	29	1·00	·90	1·43	·82	·73	·55	·27	·47	·49	·75	·73	1·03	9·17
			Means .		.	1·16	1·12	1·62	·86	·64	·35	·24	·36	·66	·71	·81	96	9·48

VII.—*East Central Karroo.*

	Ref. No.	S lat	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr	May	June	July.	Aug	Sept.	Oct.	Nov	Dec	Year
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Aberdeen	109	32° 28′	24° 3′	2400	29	1·61	1·73	2·06	·84	·70	·30	·29	·48	·91	1·13	1·25	1·37	12·67
Aberdeen Road	110	32 46	24 20	2480	23	1·18	1·30	1·81	·80	·56	·30	·27	·41	·77	·73	1·09	1·23	10·45
Colonies Plaats	111	31 59	24 50	4750	22	1·91	1·99	2·49	1·11	·87	·42	·32	·54	·70	·79	1·22	1·56	13·92
Cranemere	112	32 30	25 0	2750	27	1·39	1·50	2·06	1·05	·94	·46	·46	·62	·96	1·08	1·17	1·58	13·25
Goliads Kraal	113	32 8	24 42	3500	30	1·71	2·20	2·54	1·22	1·08	·31	·55	·74	·62	1·26	1·49	1·36	15·08
Graaff Reinet	114	32 16	24 32	2500	29	1·51	1·73	2·40	1·12	1·21	·51	·46	·67	1·17	1·33	1·48	1·68	15·27
Jansenville	115	32 56	24 40	—	29	1·25	1·20	1·73	·92	·64	·33	·21	·44	·96	·84	1·22	1·31	11·05
Kendrew	116	32 30	24 30	2015	23	1·43	1·49	1·65	1·01	·75	·26	·32	·46	1·02	1·04	1·26	1·96	12·63
Klipdrift (De Erf)	117	32 23	24 29	2400	26	1·37	1·53	1·46	·77	·69	·26	·25	·43	·89	1·00	1·15	1·32	11·12
Middleton	118	32 57	25 49	1672	26	1·36	1·76	1·91	1·61	1·06	·55	·42	·60	·91	1·19	1·48	1·66	14·51
New Bethesda	119	31 52	24 34	—	23	2·07	2·34	2·14	1·32	·52	·48	·29	·54	·95	1·14	1·43	1·80	15·02
Pearston	120	32 40	25 7	—	15	1·67	2·15	1·76	1·23	1·09	·56	·25	·60	1·09	1·14	1·05	1·85	14·44
Roodebloem	121	32 9	24 36	2500	27	1·29	1·66	1·87	·79	·89	·36	·42	·46	·79	·87	1·06	1·31	11·77
Somerset East	122	32 44	25 35	2400	28	2·85	3·27	3·25	2·04	1·34	·84	·69	1·01	2·03	2·76	2·61	3·19	25·90
Toegedacht	123	32 44	24 45	1900	15	1·22	1·35	1·29	·68	·53	·23	·11	·44	·85	·76	·91	1·33	9·73
Walsingham	124	32 28	25 10	—	25	1·87	1·56	2·11	1·28	1·16	·54	·55	·66	1·14	1·26	1·21	1·67	15·00
Wellwood	125	31 59	24 38	4000	29	1·70	1·77	2·53	1·31	·95	·49	·36	·49	·73	·92	1·24	1·35	13·83
Winterhoek	126	32 15	24 38	2800	29	1·70	2·15	2·67	1·27	1·24	·62	·52	·71	1·46	1·69	1·91	2·00	17·93
			Means			1·62	1·82	2·10	1·13	·90	·43	·36	·57	1·00	1·16	1·35	1·64	14·09

VIII.—*Northern Karroo.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
A. WEST.				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Beyersfontein	127	31° 10′	22° 30′	4500	8	1·61	1·95	1·73	·66	·81	26	·02	·11	·75	·58	·54	·85	9·87
Brakfontein	128	31 49	23 2	3947	29	1·30	1·38	1·94	·89	·68	·31	·26	·24	·47	·71	·85	·93	9·96
Brandvlei	129	30 27	20 32	3050	5	·56	·62	·56	·68	·28	·34	·44	·08	·47	·48	·07	·34	4·92
Calvinia	130	31 29	19 46	3100	25	·29	·44	·65	1·16	1·05	·89	·72	·81	·57	·51	37	·22	7·68
Carnarvon	131	30 58	22 8	4060	29	1·30	1·21	1·48	·95	·59	·30	·19	·27	·31	·50	·53	·51	8·14
Fraserburg	132	31 54	21 31	4200	29	·82	·78	1·05	·94	·59	·38	·24	·31	·31	·40	·47	·34	6·64
Gannapan	133	30 21	22 0	—	19	·53	·46	·92	·63	·47	·11	·08	·09	·28	·30	·37	·31	4·55
Loxton	134	31 27	22 25	—	8	·65	·71	1·18	·74	·43	·18	·50	·23	·35	·42	·23	·65	6·27
Middlepost	135	31 58	20 7	—	20	·32	·32	·81	·81	·57	·34	·30	·30	·35	·30	·30	·21	4·93
Omdraais Vlei	136	30 6	23 9	3370	9	1·01	1·61	1·91	1·12	·99	·19	·40	·06	·81	·16	·41	·87	9·54
Rheboksfontein	137	31 24	21 35	—	21	·56	·61	·98	·58	·48	·27	·13	·21	·16	·42	·42	·40	5·22
Scorpion's Drift	138	31 3	21 34	—	8	·39	·49	·92	·48	·29	·12	·24	·00	·35	·23	·47	·17	4·15
Sutherland	139	32 25	20 42	4776	28	·50	·67	·96	1·15	1·27	·93	·65	·76	·72	·70	·50	·44	9·25
Victoria West	140	31 25	23 7	4100	29	1·10	1·84	1·67	1·01	·85	·36	·22	·27	·51	·67	·65	·94	10·09
Wagenaars Kraal	141	31 48	22 48	4500	22	1·32	1·47	1·97	·83	·75	·24	·23	·20	·38	·77	·80	1·00	9·96
Williston	142	31 20	20 50	3460	20	·46	·72	1·08	·58	·45	·29	·24	·23	·25	·36	·44	·34	5·44
			Means			·80	·95	1·24	·83	·66	·34	·30	·26	·44	·47	·46	·53	7·29
B. EAST.																		
Boschfontein	143	30° 47′	24° 36′	4260	15	1·72	1·65	2·23	1·32	·77	·49	·14	·22	·77	·91	·99	1·35	12·56
Britstown	144	30 35	23 33	3680	21	1·15	1·80	2·15	1·55	·78	·42	·27	·17	·64	·70	·83	1·03	11·49
Colesburg	145	30 43	25 7	4470	29	2·21	2·23	2·56	1·53	1·09	·53	·33	·46	·70	1·06	1·12	1·57	15·49
Cradock	146	32 11	25 38	2850	29	2·20	2·29	2·10	1·25	·81	·44	·33	·45	·73	1·11	1·25	1·70	14·65
De Aar	147	30 38	24 2	4800	18	1·62	2·50	2·27	1·64	·88	·60	·20	·18	·75	·86	1·31	1·10	13·91
Hanover	148	31 3	24 26	4500	29	1·72	2·06	2·37	1·61	1·04	·50	·37	·38	·68	·87	1·05	1·23	13·88
Kleinhaasfontein	149	31 56	26 28	—	19	3·13	3·20	2·56	1·52	·79	·56	·38	·69	1·04	1·48	1·87	2·78	20·00
Middelburg	150	31 30	25 0	4095	29	1·98	2·15	2·35	1·20	·84	·43	·33	·41	·64	1·02	1·23	1·48	14·05
Middlemount	151	31 29	24 21	6045	12	1·70	1·96	2·34	1·22	·61	·48	·27	·24	·53	·93	·74	1·55	12·57
Murraysburg	152	31 57	23 48	3800	29	1·25	1·78	2·01	·99	·98	·37	·29	·36	·48	·72	·86	1·03	11·11
Naauwpoort	153	31 10	24 57	4884	23	1·82	2·29	2·50	1·64	1·02	·57	·33	·40	·64	·82	1·13	1·61	14·77
Phillipstown	154	30 25	24 30	4500	29	1·76	2·10	2·46	1·28	1·02	·41	·30	·36	·55	75	·99	1·30	13·28
Richmond	155	31 25	23 57	4700	28	1·62	2·14	2·27	1·39	1·23	·52	·36	·35	·47	·95	·92	1·21	13·45
Steynsburg	156	31 18	25 49	4850	29	2·59	2·60	2·88	1·44	·92	·55	·43	·47	·92	1·10	1·38	2·21	17·49
Stonehills	157	32 2	25 38	—	18	2·49	2·09	2·46	1·39	·65	·45	·46	·58	·67	1·24	1·40	1·76	15·64
Tarkastad	158	32 0	26 15	4300	29	2·75	2·67	2·88	1·55	1·09	·63	·53	·69	·91	1·34	1·55	2·36	18·94
Varsch Vlei	159	31 40	25 45	5400	18	2·13	3·13	1·88	1·30	·86	·42	·33	·45	·56	·90	1·28	1·43	13·68
Witmoss	160	32 32	25 40	2396	23	1·99	2·08	2·21	1·34	·78	·50	·41	·66	·88	1·20	1·35	1·98	15·38
			Means			1·99	2·21	2·36	1·40	·90	·49	·34	·42	·70	1·00	1·18	1·59	14·57

IX.—*Northern Cape Province.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
A. West.				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
The Halt	161	27° 50′	20° 20′	5000	9	·75	1·02	1·34	·82	·14	·04	·09	00	·03	·27	·33	·59	5·41
Kenhardt	162	29 18	21 9	2700	29	·60	1·02	1·08	·76	·37	·17	·15	·08	·12	·42	·21	·54	5·50
Prieska	163	29 39	22 45	3300	29	1·45	1·27	2·03	1·48	·64	·20	·19	·14	·28	·54	·62	·90	9·74
Trooilapspan . . .	164	28 40	22 31	—	9	·85	·99	1·52	·69	·32	·08	·25	·00	·17	·36	·23	·64	6·10
Upington	165	28 26	21 15	2800	22	·90	·88	1·56	·82	·51	·09	·10	·06	·20	·63	·48	·74	6 97
Van Wyks Vlei . .	166	30 23	21 50	3300	23	·73	1·02	1·40	·79	·51	·14	·19	·09	·16	·31	·42	·56	6·32
			Means	.	.	·88	1·03	1·49	·89	·42	·12	·16	·06	·16	·42	·38	·66	6·67
B. East.																		
Avoca	167	29° 4′	23° 53′	3900	25	2·02	2·05	2·82	1·35	·63	·25	·14	·24	·26	·57	·89	1·85	13·06
Barkly West . . .	168	28 30	24 30	3800	26	3·28	3·12	3·16	1·66	·67	·36	·25	·25	·47	·91	1·60	2 89	18·59
Bellsbank	169	28 8	24 45	3840	12	4 14	3·02	3·54	1·05	·31	·16	·13	·17	·37	·47	1·35	2·54	17·25
Groet Boetsap . . .	170	27 56	24 25	—	13	3·77	4·18	3·84	2·18	·61	·45	·12	·20	·11	·87	1·86	3·03	21·22
Campbell	171	28 45	23 43	4100	22	2·08	2·32	2·58	1·56	·46	·26	·14	·23	·34	·66	·92	2·12	13·67
Douglas	172	29 3	23 47	3500	23	2·55	2·38	2·95	1·46	·74	·31	·19	·18	·33	·59	·90	1·45	14 03
Dunmurry	173	28 51	23 16	4300	16	2·09	2·30	2·58	1·89	·66	·28	·27	·14	·43	·58	·81	1·66	13 69
Eskdale	174	29 26	23 58	3500	13	2·31	1·65	2·65	1 34	·58	·44	·19	·16	·40	·68	1·00	1·55	12·96
Griquatown . . .	175	28 52	23 17	3560	24	2·06	2·11	2 45	1·63	·82	·43	·16	·21	·40	·93	·87	1·58	13·66
Hopetown	176	29 36	24 6	3600	29	2·07	1·75	2·83	1·18	·86	·31	·26	·20	·44	·84	·95	1·34	13·03
Karee Kloof . . .	177	29 48	23 16	3900	8	1·24	1·37	1·36	·69	·56	·08	·26	·05	·76	·51	·39	·96	8·23
Kimberley	178	28 43	24 46	4000	40	2·79	3·06	3·06	1·41	·85	·32	·37	·26	·77	1 00	1·56	2 12	17·57
Newlands	179	28 20	24 25	—	24	3·19	3·32	3·05	1·54	·57	·31	·17	·16	·35	·80	1·47	2 71	17·64
Orange River Station .	180	29 38	24 12	3520	14	1·92	1·68	2 05	·87	·61	·22	·18	·13	·50	·51	·65	·98	10 30
Riverton	181	—	—	—	28	2·88	2·58	2·60	1·60	·77	·32	·20	17	·44	1·05	1·51	2·41	16·53
			Means	.	.	2·56	2·46	2·77	1·43	·65	·30	·20	·18	·42	·73	1·12	1 95	14·76

X.—*South-Eastern Cape Province.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Alexandria	180A	33° 28′	26° 25′	—	24	1·85	1·92	2·07	2·50	2·03	1·82	1·69	2·57	2·76	2·81	3·40	2·16	27·58
Alice	181A	32 47	26 50	1700	27	2·48	2·75	2·99	1·91	1·55	·98	·86	1·06	1·53	2·06	2·65	2·49	23·31
Alicedale	182	33 20	26 5	910	27	1·43	1·10	1·57	1·40	1·26	·84	·72	·85	1·36	1·35	1·53	1·46	14·87
Atherstone	183	33 19	26 23	2250	27	2·09	2·09	2·48	2·01	1·55	1·00	·92	1·22	1·99	2·46	2·24	2·39	22·44
Bedford	184	32 41	26 6	2460	29	3·07	3·40	3·69	2·33	1·47	·90	·81	1·11	1·84	2·74	2·93	3·07	27·36
Cathcart	185	32 18	27 9	3900	29	3·81	4·05	4·04	2·15	·87	·54	·60	·80	1·29	2·27	2·87	3·45	26·75
Cullendale	186	32 39	26 12	—	24	2·85	2·84	3·07	2·31	1·19	·71	·63	·92	1·86	2·59	2·53	3·16	24·66
Daggaboer	187	32 32	25 52	2900	21	2·54	2·10	2·61	1·70	1·13	·86	·27	·73	1·28	1·54	1·73	2·23	18·72
Dohne	188	32 32	27 37	3040	27	3·34	3·46	3·19	1·95	1·22	·67	·48	1·00	1·57	2·92	3·19	3·13	26·12
East London	189	33 2	27 56	104	26	3·14	3·19	3·44	3·07	2·12	1·66	1·00	2·30	2·99	4·01	3·34	3·21	33·50
Evelyn Valley	190	32 35	27 15	4250	22	7·80	7·04	7·33	5·13	3·20	2·47	1·42	3·05	5·27	7·85	7·19	7·41	65·17
Fort Beaufort	191	32 46	26 37	1500	29	2·42	2·73	3·00	2·01	1·23	·64	·60	·85	1·65	2·09	2·43	2·24	21·89
Fort Jackson	192	32 56	27 42	1110	27	2·36	2·27	2·64	2·36	1·39	1·12	·63	1·46	2·14	3·05	2·71	2·80	24·94
Grahamstown	193	33 18	26 32	1800	29	2·24	2·69	2·96	2·32	1·88	1·33	1·00	1·50	2·26	3·13	3·25	2·59	27·16
Hogsback	194	32 36	26 55	3750	24	5·93	6·05	5·54	3·73	2·30	1·56	1·31	2·18	2·75	5·43	4·90	6·37	48·05
Kabusie	195	32 35	27 29	2400	27	3·03	3·22	2·47	1·90	·99	·76	·34	1·11	1·44	2·44	1·99	2·76	22·45
Lower Katberg	196	32 29	26 40	3380	26	5·80	5·52	4·99	3·02	1·75	1·13	·89	1·63	2·81	4·81	4·85	5·75	42·94
Kei Road	197	32 44	27 33	2330	28	3·53	4·13	3·62	2·55	1·41	1·06	·74	1·31	2·23	3·58	3·08	3·47	30·71
King William's Town	198	32 52	27 23	1315	29	2·30	2·90	2·86	2·34	1·41	1·04	·68	1·25	2·05	2·75	2·69	2·64	24·90
Kologha	199	32 31	27 22	2200	24	4·87	5·17	4·66	2·95	1·39	·95	·71	1·49	2·24	3·81	4·21	5·14	37·58
Lovedale	200	32 46	26 51	1720	24	2·81	2·71	2·75	1·92	1·59	·97	·93	1·00	1·60	2·22	2·50	2·45	23·47
Peddie	201	33 13	27 7	500	28	1·74	2·14	2·51	2·22	1·60	1·27	·93	1·46	2·07	2·62	2·59	2·10	23·24
Perie Forest	202	32 27	27 18	1850	27	4·82	4·46	4·51	3·24	1·70	1·24	·85	1·57	3·11	4·53	4·80	4·61	39·44
Port Alfred	203	33 34	26 54	110	27	1·77	1·74	2·16	2·70	2·26	1·76	1·46	2·27	2·88	2·93	2·86	2·33	27·12
Salem	204	33 28	26 30	500	29	1·73	1·81	2·22	2·14	1·54	1·19	·94	1·38	1·91	2·24	2·55	2·13	21·78
Seymour	205	32 33	26 47	2600	28	2·60	2·79	3·23	1·81	1·61	1·21	·88	1·19	1·50	2·05	2·30	2·47	23·66
Stutterheim	206	32 34	27 27	2945	26	3·69	3·81	3·69	2·44	1·10	·77	·50	1·14	1·77	2·98	3·11	3·61	28·61
Thomas River	207	32 28	27 17	3565	29	2·86	3·03	3·18	1·74	·89	·67	·44	·79	1·14	1·70	2·10	2·54	21·08
			Means			3·17	3·25	3·34	2·42	1·56	1·12	·83	1·40	2·11	3·03	3·09	3·22	28·55

XI.—*North-Eastern Cape Province.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Aliwal North	208	30° 41′	26° 40′	4330	29	3·51	3·87	3·85	2·02	1·10	·69	·44	·83	1·04	1·56	1·99	3·11	24·01
Barkly East	209	30 58	27 35	5830	24	3·97	3·78	3·28	1·91	1·07	·78	·51	1·15	1·19	1·57	2·21	3·29	24·71
Buffelsfontein . . .	210	31 22	26 40	6000	24	3·21	3·18	3·16	1·74	1·03	·72	·49	·85	1·08	1·46	2·28	2·75	21·95
Burghersdorp . .	211	31 2	26 19	4500	28	2·58	3·06	3·25	1·69	1·00	·57	·49	·78	·84	1·37	1·56	2·32	19·51
Contest	212	31 58	27 18	3000	22	3·09	3·25	2·54	1·67	·70	·40	·51	·69	·75	1·50	1·78	2·87	19·74
Cyphergat	213	31 27	26 25	5150	23	2·75	3·34	2·94	1·74	1·03	92	·61	·66	1·07	1·47	1·80	2·94	21·27
Dordrecht	214	31 22	27 2	5500	29	3·66	3·60	3·34	1·60	1·04	·61	·46	·89	1·22	1·70	2·45	3·13	23·70
Ellesmere	215	30 42	26 20	4400	25	2·65	3·00	2·92	1·60	·87	·60	·34	·69	·85	1·17	1·39	2·43	18·51
Herschel	216	30 36	27 9	5100	26	4·50	4·02	4·16	2·66	1·24	·81	·41	1·00	1·36	1·98	2·37	3·51	28·01
Jamestown	217	31 7	26 47	5000	29	3·37	3·23	3·21	1·67	1·08	·68	·48	1·02	1·06	1·49	1·93	2·54	21·76
Lady Frere	218	31 42	27 13	3400	24	3·98	4·11	3·68	1·48	·65	·59	·53	·79	1·20	1·69	2·55	3·45	24·71
Molteno	219	31 23	26 22	5180	16	3·15	2·56	3·58	1·69	1·11	·94	·32	·73	·79	1·45	1·97	3·23	21·52
Queenstown	220	31 54	26 52	3500	29	3·55	3·76	3·30	1·62	·95	·58	·56	·75	1·09	1·63	2·23	3·19	23·21
Sterkstroom	221	31 33	26 33	4430	23	2·88	3·21	3·01	1·51	·82	·71	·50	·60	1·00	1·44	2·00	3·10	20·79
Thibet Park	222	32 10	26 27	4200	24	2·95	2·88	3·00	1·57	·97	·67	·47	·81	·94	1·50	1·68	2·83	20·28
Tylden	223	32 7	27 5	2900	27	3·47	2·74	2·63	1·55	·62	·41	·46	·61	·98	1·45	1·92	2·59	19·42
Venterstadt	224	30 47	25 47	4135	25	2·36	2·89	2·97	1·72	1·28	·96	·46	·61	·71	1·38	1·43	2·22	18·98
			Means .		.	3·27	3·32	3·22	1·73	·97	·68	·47	·79	1·01	1·52	1·98	2·91	21·89

XII.—*Kaffraria.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Butterworth	225	32° 21′	28° 8′	1990	19	3·04	3·12	2·99	2·59	1·15	1·01	·31	·88	1·80	2·33	2·70	2·93	24·85
Cala	226	31 31	27 40	4500	13	4·01	3·74	3·48	1·54	·51	·38	·44	1·06	1·23	1·49	2·93	3·57	24·41
Cofimvaba	227	31 56	27 48	—	12	4·09	3·95	4·01	1·60	·70	·39	·18	·69	1·06	2·06	1·78	3·74	24·25
Elliotdale	228	31 57	28 42	600	17	2·67	2·87	3·43	2·24	1·06	1·25	·36	·68	2·24	2·66	2·85	2·78	25·09
Engcabo	229	31 41	28 0	—	18	4·37	4·02	4·38	2·44	1·10	·75	·42	·87	1·82	2·76	3·37	4·94	31·24
Ida Xalanga	230	31 25	27 39	4100	21	4·23	4·50	3·42	2·00	·86	·44	·50	·96	1·37	1·93	2·95	4·07	27·23
Indutywa	231	32 2	28 22	—	19	2·67	2·99	2·90	1·92	·88	·49	·29	·64	1·50	2·07	2·42	2·24	21·01
Kentani	232	32 30	28 18	—	19	2·43	3·30	3·01	2·64	1·36	1·34	·39	1·15	2·36	3·81	3·35	3·59	28·73
Kokstad	233	30 33	29 26	4285	25	4·41	4·04	3·40	1·61	1·03	·56	·17	·67	1·31	1·86	3·47	4·07	26·60
Maclear	234	31 4	28 21	4300	16	5·94	4·88	4·27	2·36	·81	·33	·51	·92	1·84	2·49	3·89	5·48	33·72
Main	235	31 55	27 59	3010	21	3·78	3·37	3·58	2·19	·85	·76	·59	·84	1·60	1·98	2·69	3·61	25·84
Matatiele	236	30 15	28 46	4900	11	5·46	3·70	3·57	1·67	·84	·36	·10	·81	1·44	2·36	3·52	4·26	28·09
Mount Fletcher	237	30 42	28 30	5500	18	4·50	4·22	3·66	1·79	·70	·60	·15	·70	1·57	2·16	3·04	4·91	28·00
Mqanduli	238	31 46	28 43	2390	12	3·50	2·98	3·92	2·21	1·09	·88	·62	1·05	2·85	3·24	3·38	3·49	29·21
N'qamakwe	239	32 8	27 58	3500	19	3·77	4·18	3·64	2·74	1·18	1·21	·43	1·26	1·86	2·80	2·61	3·50	29·18
Port St. John's	240	31 38	29 35	22	20	4·63	5·59	4·42	4·57	1·81	2·23	·77	2·10	3·85	6·13	5·19	5·37	46·66
Qumbu	241	31 10	28 52	3200	13	4·38	4·17	3·80	2·19	1·10	·48	·31	1·21	1·68	3·00	3·72	4·65	30·69
Somerville	242	31 12	28 37	3200	15	3·58	3·94	3·36	2·06	·68	·59	·17	·76	2·00	2·39	3·54	4·94	28·01
Tsomo	243	32 8	27 41	—	18	3·34	3·38	2·87	1·89	·68	·55	·29	·87	1·15	1·98	2·25	3·51	22·76
Umtata	244	31 35	28 46	2400	26	3·32	3·45	3·40	2·01	1·11	·76	·59	·85	1·68	2·47	2·72	3·07	25·43
Umzimkulu	245	30 15	29 56	2500	23	3·82	4·00	3·31	1·81	·96	·47	·24	·76	1·47	2·44	3·49	4·30	27·11
Willowvale	246	32 16	28 29	—	17	4·36	4·48	4·39	3·31	1·70	1·53	·49	1·66	3·79	5·61	5·08	5·18	41·58
Woodcliff	247	31 0	28 10	—	14	7·59	6·08	5·40	2·45	·83	·41	·17	·99	2·45	3·22	4·70	5·75	40·04
			Means			4·08	3·95	3·68	2·25	1·00	·77	·37	·97	1·91	2·75	3·29	4·08	29·12

XIII.—*Basutoland.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Butha Buthe	248	28° 40′	28° 12′	5500	10	6·53	3·95	4·03	2·04	·96	·47	·64	1·20	1·54	2·60	3·83	4·55	32·34
Leribe	249	28 54	28 12	5210	14	7·14	3·85	4·52	2·31	1·12	·61	·50	·95	1·37	2·62	3·28	4·86	33·13
Mafeteng	250	29 54	27 7	5600	21	5·48	4·47	4·30	2·85	1·49	·77	·63	·97	1·33	1·94	2·91	4·49	31·63
Maseru	251	29 17	27 30	5065	20	5·81	4·36	4·48	2·19	1·23	·91	·46	·58	1·66	2·59	3·22	3·23	30·72
Mohalies Hoek	252	30 8	27 28	—	15	4·64	4·15	4·20	2·25	1·74	·79	·44	·80	1·55	2·34	2·51	4·59	30·00
Moyeni	253	30 23	27 45	6000	21	5·62	4·70	5·14	3·11	1·87	·96	·47	1·22	1·46	2·72	3·42	5·24	35·93
Qachas Nek	254	30 20	27 48	6236	15	6·06	6·32	4·32	2·30	1·33	·65	·18	·67	1·87	3·03	3·30	6·00	36·03
Teyateyaneng	255	29 8	27 45	5690	17	6·25	4·05	4·48	2·49	1·22	·80	·40	·84	1·29	2·86	2·73	4·39	31·80
			Means			5·94	4·48	4·43	2·44	1·37	·75	·47	·90	1·51	2·59	3·15	4·67	32·70

XIV.—*Orange Free State.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Alma	256	28° 53′	27° 28′	—	14	5·57	3·79	3·17	2·09	1·28	·49	·59	·71	1·15	2·15	2·69	4·29	27·97
Bethulie	257	30 27	25 59	4290	23	2·84	3·11	3·21	1·50	·88	·57	·38	·58	·71	1·26	1·25	2·61	18·90
Bloemfontein	258	29 7	26 13	4510	31	3·75	3·34	3·59	1·95	1·10	·42	·31	·47	·80	1·65	2·18	2·38	21·94
Boshof	259	28 31	25 12	4100	8	3·22	3·20	3·89	1·99	·83	26	·15	·36	·65	1·69	2·16	1·53	19·93
Fauresmith	260	29 41	25 19	—	7	2·06	2·49	3·45	2·24	1·07	·44	·56	·23	·81	1·28	·95	2·36	17·94
Frankfort	261	27 15	28 35	4500	6	4·06	3·79	2·88	1·44	1·32	·04	·53	·45	·82	3·07	3·27	4·43	26·10
Harrismith	262	28 15	29 10	5326	13	4·60	3·76	2·96	1·77	1·04	·36	·20	·64	1·21	2·32	3·95	3·14	25·95
Hoopstad	263	27 48	25 54	—	12	4·05	3·86	3·34	2·10	·63	·14	·12	·51	·76	1·45	2·59	2·65	22·20
Jacobsdal	264	29 6	24 49	—	18	2·99	2·77	3·42	1·75	1·36	·57	·31	·36	·58	1·05	1·88	2·85	19·89
Jagersfontein	265	29 42	25 30	—	13	3·17	2·63	2·98	1·91	1·15	·53	·53	41	·60	1·22	1·65	1·77	18·55
Kroonstad	266	27 43	27 18	4500	31	4·39	3·76	3·68	1·92	1·07	·24	·25	·44	·86	1·94	3·19	2·95	24·69
Ladybrand	267	29 8	27 31	5000	21	5·51	4·28	4·01	2·38	1·31	·60	·59	·78	1·53	2·45	3·64	3·52	30·60
Lindley	268	27 50	28 0	—	12	4·41	3·31	3·31	1·47	1·24	·19	·39	·40	·95	2·23	2·62	3·47	23·99
Philippolis	269	30 13	25 18	4700	19	3·28	3·29	3·52	1·70	1·32	·63	·38	·43	·50	·98	1·64	1·73	19·40
Smithfield	270	30 10	26 21	4400	19	3·90	3·21	3·36	2·15	1·13	·51	·44	·86	·82	1·16	1·77	2·77	22·08
Thaba 'Nchu	271	29 8	26 51	4920	11	4·66	3·63	3·95	1·91	·94	·50	·56	·47	1·56	2·16	2·21	2·58	25·13
Wepener	272	29 41	27 1	4700	10	5·37	2·94	4·26	2·24	1·45	·69	·60	·70	·66	1·54	2·27	4·87	27·59
Winburg	273	28 29	27 2	4600	9	3·10	4·10	4·37	1·81	·68	·20	·23	·60	·20	2·07	2·61	1·99	21·96
			Means			3·94	3·40	3·52	1·91	1·10	·41	·40	·52	·84	1·76	2·36	2·88	23·04

XV.—*Natal.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Dundee	274	28° 10′	30° 14′	4098	13	5·93	4·81	3·76	2·62	1·07	·20	·13	·65	·99	2·92	3·26	4·08	30·42
Durban	275	29 51	31 0	260	32	4·31	4·68	5·06	3·48	1·94	1·07	·79	1·64	3·23	4·93	4·60	4·81	40·54
Estcourt	276	29 1	29 52	3833	15	5·45	4·78	3·62	1·80	·47	·33	·16	·58	1·00	2·35	3·31	4·34	28·19
Greytown	277	29 4	30 35	3416	14	5·53	4·99	4·45	2·02	·99	·30	·15	1·14	1·68	3·63	5·43	5·67	35·98
Howick	278	29 29	30 14	3400	14	5·26	4·78	4·11	2·30	·59	·55	·15	·94	1·67	3·10	4·32	4·56	32·33
Impendhle	279	29 36	29 51	—	6	8·12	5·43	4·63	3·50	·67	·27	·07	·32	·90	2·53	3·46	5·48	35·38
Ladysmith	280	28 33	29 47	3284	7	3·87	4·00	5·15	2·15	·85	·30	·07	·82	·75	2·64	2·44	3·16	26·20
Mapumulo	281	29 12	31 4	3450	7	4·56	4·35	4·85	1·72	1·15	·59	·66	1·35	2·31	2·58	5·54	5·30	34·96
Maritzburg	282	29 36	30 21	2218	37	5·15	5·00	4·53	2·77	·84	·21	·29	1·17	1·84	3·34	4·89	5·35	35·38
Merebank	283	30 0	31 0	30	9	2·58	5·32	6·93	5·48	1·27	1·05	1·07	3·39	2·14	4·51	5·68	4·87	44·29
Ndwedwe	284	29 29	30 51	—	5	4·93	6·02	4·03	2·46	1·06	2·36	·45	·64	2·16	3·30	6·45	5·56	39·42
Newcastle	285	27 46	29 56	3893	14	6·79	5·92	5·16	2·16	·78	·17	·07	·61	1·28	3·00	4·17	5·50	35·61
New Hanover	286	29 21	30 30	2595	14	5·40	5·58	4·16	2·78	1·30	·53	·22	1·07	2·04	3·67	5·09	4·72	36·56
Ottawa	287	29 40	31 3	140	10	4·14	4·32	4·92	4·04	1·15	1·00	1·62	1·23	2·05	3·09	5·78	5·44	38·78
Port Shepstone	288	30 44	30 27	50	13	4·53	4·69	5·00	4·59	1·38	·90	·82	1·78	5·50	5·56	5·96	5·60	46·31
Richmond	289	29 52	30 16	2816	15	5·95	6·02	4·42	3·47	1·30	·51	·26	1·21	2·39	3·73	5·36	6·49	41·11
Stanger	290	29 21	31 17	142	17	4·63	3·71	4·90	2·73	1·81	1·00	·72	1·32	3·74	5·40	5·93	5·46	41·35
Upper Tugela	291	—	—	—	4	5·68	4·26	4·29	2·86	1·08	·17	·18	·60	1·06	2·73	3·15	5·90	31·96
Umsinga	292	28 34	30 27	—	5	5·63	4·19	4·44	1·41	1·00	·19	·07	·41	·93	3·29	2·52	4·74	28·82
Umzinto	293	30 18	30 39	—	15	3·43	4·73	4·98	3·26	2·19	·93	·35	1·08	4·19	6·03	5·15	4·27	40·59
Verulam	294	29 38	31 3	169	17	4·10	4·07	4·77	3·79	1·97	·57	·36	1·12	3·29	5·75	4·56	4·60	38·95
Weenen	295	28 51	30 5	2841	14	5·26	4·25	3·05	2·03	·64	·20	·12	·79	·98	2·32	3·40	3·42	26·47
Winkle Spruit	296	30 4	30 35	—	6	2·90	6·60	4·14	5·93	1·45	2·30	·63	·67	4·45	5·77	6·17	4·69	45·70
			Means			4·96	4·89	4·58	3·02	1·17	·68	·41	1·07	2·20	3·75	4·64	4·96	36·32

XVI.—*Zululand.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Eshowe	297	28° 54′	31° 20′	—	9	7·61	4·54	7·14	3·14	2·00	1·22	·63	1·69	4·11	5·94	7·54	8·04	53·60
Hlabisa	298	28 8	31 49	—	7	5·30	5·09	5·74	2·75	·95	·73	·65	1·16	2·05	4·92	5·77	5·17	40·28
Mahlabatini	299	28 17	31 30	—	6	3·82	4·78	2·41	2·98	·38	·07	·15	·72	1·68	4·50	5·89	4·03	31·41
Melmoth	300	28 35	31 24	—	13	5·31	3·34	3·81	2·01	1·30	·64	·27	1·03	1·66	3·55	4·73	4·86	32·51
Nkandhla	301	28 38	31 8	3700	10	4·49	4·10	4·89	2·28	·94	·80	·22	·76	1·70	3·22	5·86	5·08	34·34
Nondweni	302	28 14	30 58	—	4	5·17	3·33	3·80	1·83	1·10	·29	·01	·92	·94	2·16	3·27	3·82	26·64
Nongoma	303	28 10	31 25	—	10	6·14	3·91	5·01	2·11	1·40	·41	·41	·86	1·80	3·40	4·57	4·83	31·85
Nqutu	304	28 18	30 35	—	4	5·27	4·72	4·16	2·29	·32	·63	·14	·29	·76	1·86	4·86	3·14	28·44
Qudeni	305	28 35	30 40	6000	7	8·80	6·26	7·32	3·54	1·78	1·29	·42	1·52	2·12	4·44	7·15	7·18	51·82
Ubombo	306	27 35	32 7	—	6	4·40	4·52	2·35	3·02	1·28	50	·33	1·19	1·90	6·99	5·72	4·56	36·76
			Means	.	.	5·63	4·46	4·66	2·60	1·14	·66	·32	1·01	1·87	4·10	5·54	5·07	37·06

XVII.—*Bechuanaland.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Armadillo Creek	307	—	—	—	6	2·59	3·21	2·37	1·42	·53	·15	·30	·06	·72	·97	1·18	1·69	15·19
Chawabe	308	—	—	—	5	2·48	3·46	1·39	·67	·64	·02	·09	·02	·02	1·52	·77	·83	11·91
Doornbult	309	26° 30′	25° 20′	4042	7	2·78	5·15	2·82	1·59	1·10	·25	·15	·23	·14	1·44	1·20	2·50	19·35
Kuruman	310	27 25	23 26	—	10	4·00	3·84	3·03	1·39	·86	·28	·36	·08	·64	·48	1·60	1·97	18·53
Lobatsi	311	25 10	25 30	3915	5	5·46	5·26	2·63	1·37	·94	·04	·03	·19	·06	1·64	1·34	2·12	21·08
Mafeking	312	25 40	25 52	4194	24	4·86	4·13	4·66	1·81	·32	·00	·44	·29	·61	1·52	2·57	3·29	24·50
Masilibitsani	313	26 48	23 40	—	7	2·69	3·09	2·70	1·02	·48	·11	·18	·06	·68	·87	·67	1·45	14·00
Mochudi	314	24 21	26 6	3105	5	3·05	4·02	1·79	·85	1·45	·23	·01	·16	·40	1·71	1·87	3·52	19·06
Molepolele	315	24 24	25 32	3600	4	3·32	2·40	3·16	1·47	·00	·53	·01	·00	·23	1·29	3·47	3·32	19·20
Mopasgom	316	—	—	—	4	2·00	2·38	2·15	1·52	1·14	·00	·07	·03	·00	1·73	·95	1·13	13·10
Morokwen	317	27 4	24 33	—	9	2·64	2·53	2·92	1·60	·40	·09	·30	·01	·59	·78	1·37	1·02	14·25
Palapye Road	318	22 33	27 10	3011	8	3·41	2·79	3·41	1·18	·45	·05	·00	·00	·22	·95	1·75	2·27	16·48
Serowe	319	22 24	26 45	—	4	2·36	3·16	4·40	·77	·85	·00	·00	·00	·11	1·28	1·46	1·99	16·38
Setlagoli	320	26 16	25 8	—	11	3·48	4·00	2·68	1·39	·76	·02	·19	·15	1·12	1·58	2·00	1·84	19·21
Taungs	321	27 48	24 47	3589	15	3·78	3·23	3·20	1·45	·38	·22	·12	·11	·58	1·03	1·38	1·96	17·44
Tsau	322	20 11	22 30	—	4	2·84	5·00	1·60	·71	·22	—	·00	·01	·01	·39	·76	1·05	12·59
Vryburg	323	26 55	24 43	4300	22	4·53	3·53	3·52	1·34	·68	·25	·17	·21	·43	1·01	1·47	2·62	19·76
Zwartlaagte	324	25 52	25 20	—	6	3·15	3·95	2·87	1·18	·75	·01	·20	·07	·84	1·23	2·48	2·39	19·12
			Means	.	.	3·30	3·62	2·85	1·26	·66	·13	·15	·09	·41	1·19	1·57	2·05	17·29

XVIII.—*Damaraland and Great Namaqualand.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Aminuis	325	23° 42′	19° 14′	—	15	2·09	2·87	1·61	1·19	·31	·06	·11	·03	·22	·12	·39	1·52	10·52
Berseba	326	26 0	17 41	3478	12	·51	·98	·83	·36	·02	·00	—	·00	·08	·04	·13	·36	3·31
Bethanien	327	26 28	16 51	3280	15	1·10	·87	1·10	·53	·07	·10	·02	·04	·04	·10	·17	·37	4·51
Franzfontein	328	20 9	15 16	—	14	2·15	2·30	2·32	1·10	·10	·02	—	·01	·12	·18	·33	1·38	10·01
Gibeon	329	25 15	17 47	3707	15	1·57	1·46	1·01	·46	·04	·05	·01	·01	·03	·15	·40	·39	5·58
Gobabis	330	22 21	19 1	4650	16	4·41	3·58	2·72	1·17	·28	·09	·04	·04	·08	·42	1·11	2·26	16·20
Grootfontein	331	19 44	18 2	—	14	6·10	5·04	3·76	1·85	·18	·14	—	·02	·07	·63	1·57	4·51	23·87
Hasuur	332	26 40	19 50	—	12	1·46	1·50	2·24	·40	·32	·17	·01	·04	·02	·10	·72	·61	7·59
Hohewarte	333	—	—	—	16	3·27	2·91	2·41	1·32	·39	·03	·07	—	·06	·23	·50	1·83	13·02
Karibib	334	21 58	15 51	—	12	1·97	2·05	·98	·47	·11	·02	—	·02	·06	·11	·09	1·38	7·20
Keetmanshoop	335	26 32	18 2	2733	15	·94	1·15	1·13	·67	·08	·04	·07	·00	·04	·15	·20	·33	4·80
Lüderitzbucht	336	26 40	15 0	—	12	·01	·06	·03	·04	·15	·16	·04	·11	·10	·02	·01	·05	·78
Maltahöhe	337	24 15	16 55	—	14	1·73	1·14	1·06	·90	·04	·01	·03	—	·08	·07	·18	·38	5·62
Nauchas	338	23 45	16 15	—	14	2·20	2·01	1·01	·90	·10	·06	·02	·02	·06	·22	·22	1·44	8·26
Okahandja	339	21 59	16 56	4318	20	3·43	3·82	3·14	1·28	·29	·01	·02	·11	·05	·44	·43	2·34	15·36
Okombahe	340	21 20	15 35	—	10	1·97	1·14	1·02	·51	·02	·06	·00	—	·24	·26	·19	·87	6·28
Omaruru	341	21 25	15 59	3904	17	3·46	2·83	1·44	1·26	·14	·06	·00	—	·10	·25	·25	1·30	11·09
Otjimbingwe	342	22 18	16 5	3773	13	2·09	1·77	1·06	·51	·12	·01	·01	—	·08	·10	·17	·93	6·85
Outjo	343	20 6	16 10	—	14	4·37	3·45	2·70	1·24	·13	·03	—	·03	·07	·34	·39	2·53	15·28
Rheoboth	344	23 20	17 3	4528	25	2·60	2·36	1·91	1·00	·18	·04	·01	·09	·08	·22	·46	1·02	9·97
Swakopmund	345	22 42	14 32	—	14	·10	·06	·10	·03	·04	·02	·01	·02	·02	·04	·02	·14	·60
Ukamas	346	27 58	19 40	—	13	·59	·83	1·28	·67	·18	·16	·19	·08	·04	·20	·32	·41	4·95
Walvis Bay	347	22 56	14 30	8	8	·01	·04	·00	·42	·00	·02	·00	·00	·14	·06	·00	·04	·73
Warmbad	348	28 27	18 40	2361	15	·37	·87	·80	·67	·07	·20	·15	·06	·08	·12	·10	·10	3·59
Windhuk	349	22 30	17 6	5315	23	3·66	2·90	3·07	1·59	·24	·03	·06	·09	·06	·36	·81	1·97	14·84
Zessfontein	350	19 20	13 30	—	11	·98	·82	·67	·46	·12	·01	—	—	·03	·15	·04	·68	3·96
			Means			2·04	1·88	1·52	·81	·14	·06	·03	·03	·08	·20	·35	1·12	8·26

XIX.—*S. W. Transvaal.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Bloemhof	351	27° 39′	25° 36′	4050	7	4·92	3·48	3·20	1·46	·58	·12	·26	·22	1·01	·82	2·05	1·77	19·89
Christiana	352	27 55	25 10	3970	9	3·18	4·15	3·05	1·61	·67	·08	·12	·10	·66	·61	1·66	1·54	17·43
Kaalfontein	353	26 26	26 56	4800	5	5·62	4·16	5·04	1·80	·33	·03	·07	·07	·81	1·68	2·78	3·61	26·00
Klerksdorp	354	26 52	26 40	4350	15	4·79	3·52	3·28	1·97	·71	·11	·18	·21	·55	1·42	2·62	2·85	22·21
Klerkskraal	355	26 14	27 10	4600	7	6·00	4·09	3·70	1·02	·43	·12	·22	·11	·67	1·86	3·26	3·74	25·22
Koppieskraal . . .	356	26 54	27 22	4500	6	3·55	4·21	3·21	1·70	·54	·03	·01	·11	·90	1·45	4·34	4·55	24·60
Lichtenburg . . .	357	26 10	26 10	4950	8	5·43	4·06	3·92	1·64	·65	·03	·28	·03	·75	1·08	2·43	3·64	23·94
Ottoshoop	358	25 45	25 58	4250	6	5·34	3·86	3·26	1·33	·21	·09	·31	·10	·81	1·12	3·38	2·97	22·78
Potchefstroom . . .	359	26 43	27 6	4460	9	4·22	4·55	3·09	2·09	·70	·03	·19	·15	·77	1·22	3·32	4·26	24·59
Rickersdam . . .	360	25 27	26 23	3800	6	6·15	5·35	3·60	1·33	·28	·12	·15	·11	·51	1·34	3·68	4·31	26·93
Schweizer Reneke . .	361	27 11	25 20	3900	6	3·82	4·93	2·71	1·09	·49	·06	·21	·14	·68	·45	2·05	2·38	19·01
Turffontein . . .	362	26 25	27 9	4700	7	6·35	3·76	3·16	1·43	·37	·10	·26	·09	·66	1·53	3·19	3·39	24·29
Uitkyk	363	27 28	25 50	4200	7	4·47	3·42	2·97	1·26	·58	·03	·20	·09	·88	1·20	2·27	2·84	20·21
Vaalbank	364	27 34	25 55	4140	6	3·70	3·08	3·30	1·01	·56	·06	·15	·10	1·02	·87	1·86	2·51	18·22
Vecht Valley . . .	365	27 25	25 4	3800	7	4·46	4·04	3·11	1·34	·68	·03	·10	·18	·91	·79	1·77	2·02	19·43
Ventersdorp . . .	366	26 19	26 50	4870	7	6·33	4·16	2·95	·90	·34	·05	·20	·08	·75	1·52	2·66	3·40	23·34
Wolmaransstad . . .	367	27 12	25 59	4380	7	4·88	4·78	3·72	1·44	·88	·10	·15	·12	·67	1·38	2·16	2·86	23·14
Wondilla	368	27 36	26 2	4150	6	3·90	3·90	3·44	1·45	·60	·10	·19	·13	1·00	1·10	2·46	2·76	21·03
Zeerust	369	25 32	26 5	3940	10	4·87	4·52	3·51	1·59	·92	·05	·15	·13	·38	1·43	3·15	2·78	23·48
			Means .		.	4·84	4·11	3·38	1·45	·55	·07	·18	·12	·76	1·20	2·69	3·06	22·41

XX.—*S. Transvaal.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Bethal	370	26° 27′	29° 28′	5200	8	4·98	5·27	3·07	1·29	·68	·04	·09	·53	·65	3·18	5·23	4·44	29·45
Gemsbokfontein	371	25 44	29 40	5400	7	5·68	4·27	2·72	1·46	·29	·22	·04	·33	·81	2·60	5·21	5·26	28·89
Heidelberg	372	26 30	28 22	5055	8	4·86	5·77	3·47	1·40	·62	·06	·25	·30	·80	1·81	5·66	3·53	28·53
Irene	373	25 53	28 13	4800	7	6·61	4·42	3·78	1·17	·27	·11	·11	·38	·43	2·36	4·72	3·62	27·98
Johannesburg	374	26 11	28 3	5750	25	6·19	5·08	4·23	2·06	·72	·13	·24	·35	·88	2·27	4·24	4·71	31·10
Keerom	375	25 40	29 28	4690	7	5·28	4·45	3·26	1·34	·18	·18	·01	·36	·74	2·18	5·36	4·60	27·94
Middelburg	376	25 46	29 28	4700	10	5·02	4·15	3·43	1·57	·52	·10	·05	·35	·55	2·37	5·59	4·33	28·03
Modderfontein	377	26 6	28 9	5500	14	5·53	3·90	3·95	1·82	·60	·19	·15	·32	·73	2·07	4·08	3·93	27·27
Panplaats	378	25 41	29 46	5900	7	5·57	4·29	2·40	1·04	·17	·19	·01	·31	·91	2·43	5·77	4·27	27·36
Platrand	379	27 6	29 28	5450	7	4·73	4·46	3·21	1·46	·21	·05	·17	·46	·77	2·91	5·06	4·64	28·13
Pretoria (70 ft.)	380	25 45	28 11	4392	19	6·17	3·88	3·44	1·11	·71	·13	·06	·24	·82	1·99	4·25	3·83	26·63
Do. (Arcadia)	381	25 45	28 12	4387	14	5·60	4·68	3·77	1·51	·62	·16	·21	·30	·80	2·16	3·93	4·28	28·02
Schoonord	382	26 0	29 46	5200	6	6·23	4·20	3·56	1·36	·12	·11	·00	·26	·75	2·56	5·26	4·16	28·57
Springs	383	26 16	28 24	5350	7	5·33	4·69	3·86	1·18	·15	·10	·16	·31	·88	2·21	4·72	3·50	27·09
Standerton	384	26 57	29 15	4988	9	4·31	6·45	3·28	1·61	·50	·04	·19	·55	·93	2·87	4·79	4·47	29·99
Vereeniging	385	26 40	27 56	4710	11	5·17	4·92	3·65	2·02	·65	·04	·14	·27	·75	1·86	4·15	3·27	26·89
Wagen Drift	386	25 31	28 33	4000	5	6·70	5·43	3·92	1·19	·13	·19	·10	·58	·49	1·89	4·95	3·91	29·48
Zuurbekom	387	26 19	27 47	5196	13	5·77	4·20	3·75	1·67	·53	·08	·21	·30	·76	2·27	3·98	3·74	27·26
			Means			5·54	4·69	3·49	1·46	·43	·12	·12	·36	·75	2·33	4·83	4·14	28·26

XXI.—*S.E. Transvaal.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Amsterdam	388	26° 38′	30° 39′	4300	7	7·32	5·95	3·75	1·55	·17	·10	·07	·57	1·45	3·92	5·95	6·13	36·93
Athole	389	26 36	30 33	4350	10	6·41	6·32	4·65	1·80	·40	·17	·10	·69	1·34	3·74	7·89	6·87	40·38
Barberton	390	25 45	31 4	2885	19	6·41	4·51	4·14	2·06	1·05	·19	·14	·52	1·15	2·28	4·54	4·50	31·49
Bremersdorp	391	26 30	31 18	2200	8	8·77	5·36	4·46	2·86	·81	·25	·05	·54	1·46	3·81	4·74	5·58	38·69
Carolina	392	26 4	30 7	5620	8	5·62	3·68	3·00	1·86	·30	·09	·05	·23	·86	3·24	5·55	4·43	28·91
Ermelo	393	26 31	29 59	5570	14	5·17	4·09	3·31	1·63	·57	·13	·08	·31	·59	3·07	4·73	4·51	28·19
Eureka	394	25 44	31 7	1800	7	5·91	5·89	3·70	1·39	·36	·10	·19	·21	·71	2·33	4·11	4·96	29·86
Hilltop	395	25 35	31 3	3475	7	8·01	6·53	5·85	2·06	·45	·23	·03	·19	1·17	2·90	5·00	6·14	38·56
Kaapsche Hoop	396	25 35	30 46	4300	13	11·47	9·25	7·70	2·79	·70	·40	·37	·83	2·02	3·54	6·24	9·03	54·34
Komati Poort	397	25 26	31 56	460	9	3·84	5·00	4·57	1·76	·67	·19	·12	·27	·52	1·92	2·38	4·02	25·25
Lake Chrissie	398	26 17	30 12	5600	7	5·86	4·74	2·73	1·47	·09	·16	·07	·32	1·01	3·10	5·82	5·15	30·52
Mbabane	399	26 20	31 9	3826	10	9·05	8·10	6·50	3·08	1·16	·45	·62	·67	1·61	3·87	6·22	7·35	48·68
Melelane	400	25 30	31 30	1035	7	4·68	6·12	3·16	1·56	·29	·10	·03	·16	·78	1·91	3·36	5·15	27·30
Nelspruit	401	25 28	30 59	2190	7	7·32	5·85	5·87	1·48	·25	·17	·07	·31	1·00	2·32	5·05	5·76	35·45
Piet Retief	402	27 0	30 48	4000	8	6·28	5·01	4·38	2·54	·69	·11	·26	·47	1·06	4·57	6·23	5·65	37·25
Pigg's Peak	403	25 56	31 13	3800	7	10·54	8·75	7·32	2·97	·53	·43	·19	·69	1·73	3·39	6·89	7·82	51·25
Rolfontein	404	26 59	29 56	5250	6	5·07	5·06	3·00	1·35	·07	·09	·16	·36	·62	3·43	6·54	5·03	30·78
Schroedershof	405	26 35	31 53	2800	11	5·68	4·71	3·55	2·73	·40	·36	·25	·68	1·65	3·04	4·56	4·99	32·60
Volksrust	406	27 22	29 53	5296	8	6·08	6·31	4·18	1·43	·66	·15	·35	·65	·84	3·05	5·60	4·96	34·26
Wakkerstroom	407	27 21	30 8	5500	8	6·15	5·04	3·35	2·23	·51	·13	·27	·83	·91	2·94	4·61	4·99	31·96
Waterval Boven	408	25 39	30 19	4670	6	7·00	4·81	3·80	2·14	·22	·19	·00	·24	1·08	1·84	4·77	4·83	30·92
			Means			6·79	5·77	4·43	2·03	·49	·20	·17	·46	1·12	3·06	5·28	5·61	35·41

XXII.—*N.W. Transvaal.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Brakfontein . . .	409	24° 13′	28° 4′	3460	7	5·02	5·00	3·43	1·06	·20	·01	·00	·24	1·00	1·54	2·80	4·38	24·68
Geehoutkop . . .	410	24 17	28 18	3460	7	6·68	5·27	2·89	·92	·19	·01	·03	·46	·68	1·31	2·84	4·92	26·20
Gemsbokspoort . .	411	24 42	28 9	3780	6	6·39	5·31	3·59	·82	·24	·21	·12	·65	·71	1·86	2·75	6·02	28·67
Kirstenbosch . . .	412	23 42	28 18	3000	3	6·07	5·65	3·20	·33	·13	·00	·00	·42	1·08	·98	2·41	3·12	23·40
Lindley's Poort . .	413	25 29	26 41	4000	6	6·61	5·90	3·50	1·45	·35	·11	·15	·11	·52	1·13	3·12	4·20	27·15
Naauwpoort . . .	414	25 55	27 19	4000	6	5·78	4·10	4·13	·98	·35	·30	·14	·32	·61	1·64	4·58	3·80	26·73
Naboomspruit . . .	415	24 32	28 39	3460	6	5·02	4·74	2·85	·78	·22	·01	·07	·22	·82	1·41	2·95	4·53	23·62
Num Num . . .	416	24 42	28 31	3500	7	5·36	4·69	2·72	·60	·20	·03	·02	·39	·77	1·58	2·95	5·00	24·31
N.W. New Belgium . .	417	23½	27½	3000	3	5·87	3·23	2·87	·61	·40	·02	·02	·22	·23	1·07	2·22	4·11	20·87
Nylstroom . . .	418	24 42	28 20	3735	7	5·03	4·63	3·02	1·07	·26	·27	·01	·31	·76	1·73	3·79	4·90	25·78
Potgietersrust . .	419	24 12	28 57	3700	9	4·69	3·57	3·03	1·10	·45	·01	·05	·23	·54	1·43	3·71	5·06	23·87
Rhenosterpoort . .	420	24 38	28 5	3600	7	6·10	4·64	3·63	·99	·19	·09	·08	·52	·71	1·73	2·35	4·10	25·13
Rusland . . .	421	24 58	28 30	3460	7	4·51	3·84	2·19	·80	·13	·06	·08	·46	·57	1·60	3·26	5·22	22·72
Rustenburg . . .	422	25 40	27 14	3800	10	5·10	4·85	4·52	1·11	·79	·11	·19	·37	·38	1·95	3·11	4·97	27·45
Warmbaths . . .	423	24 53	28 13	3650	6	5·20	3·95	2·83	·73	·26	·00	·04	·08	·81	1·98	2·82	3·75	22·45
Zandrivierpoort . .	424	24 26	28 2	3750	7	5·91	6·24	3·39	1·18	·23	·05	·02	·42	·73	1·65	2·87	4·46	27·15
Zoutpansdrift . . .	425	25 33	27 42	3650	6	6·94	3·91	3·82	·69	·21	·06	·16	·30	·50	1·44	4·96	3·05	26·04
			Means . .			5·66	4·68	3·27	·90	·28	·08	·07	·34	·67	1·53	3·15	4·45	25·07

XXIII.—*N.E. Transvaal.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Belfast	426	25° 40′	30° 3′	6295	9	6·23	3·50	4·02	2·06	·53	·14	·04	·28	1·11	2·93	4·27	6·02	31·13
Blaauwberg	427	22 44	29 10	3400	5	8·53	6·71	3·04	·60	·14	·01	·06	·24	·57	·79	3·89	6·59	31·17
Dwars River	428	23 26	29 41	3600	6	4·12	3·79	1·93	·62	·12	·16	·00	·14	·36	·95	2·46	4·65	19·30
Elim	429	23 7	30 1	2900	7	6·32	7·83	8·00	2·08	·34	·26	·19	·20	·68	1·60	3·44	5·75	36·69
Haenertsburg	430	23 58	29 56	4500	6	11·34	5·84	7·56	1·50	·24	·21	·15	·31	·79	2·30	3·95	6·70	40·89
Klein Australia	431	22 59	30 12	4000	4	10·78	15·33	11·30	1·34	·38	·42	·72	·56	·68	1·42	4·52	10·91	58·36
Klein Letaba	432	23 20	30 49	2100	6	5·89	6·78	2·67	·94	·20	·12	·10	·18	1·20	1·90	1·80	4·52	26·30
Krabbefontein	433	23 48	30 8	2550	7	10·55	10·84	10·03	2·36	·21	·32	·21	·54	1·14	2·60	4·73	10·70	54·23
Leydsdoorp	434	24 0	30 32	2050	9	5·47	6·73	2·93	1·71	·75	·13	·05	·26	·41	1·77	3·57	5·07	28·85
Louis Trichardt	435	23 0	29 51	3120	9	4·78	6·89	4·36	1·97	·92	·39	·43	·23	·53	2·19	3·44	4·63	30·76
Lydenburg	436	25 6	30 27	4100	6	5·76	4·76	2·42	1·18	·15	·01	·00	·21	·67	1·96	3·72	4·53	25·37
Modderspruit	437	23 41	30 12	3800	7	11·62	9·69	11·26	3·09	·53	·43	·26	·44	1·29	2·59	4·85	9·16	55·21
Moddervlei	438	23 10	30 1	3900	6	6·12	7·87	7·13	2·16	·29	·29	·22	·26	·86	1·82	3·78	6·15	36·95
Pietersburg	439	23 56	29 24	4130	10	3·82	3·46	2·50	1·27	·21	·02	·08	·25	·33	1·64	2·66	3·83	20·07
Pilgrim's Rest	440	24 54	30 46	4100	21	8·18	7·73	6·49	2·43	1·15	·34	·33	·46	1·08	2·04	4·13	5·67	40·03
Pont Drift	441	22 7	29 3	1550	3	3·16	5·81	3·03	·09	·03	·25	·00	·23	·17	·41	1·67	3·69	18·54
Sabie	442	25 5	30 47	3900	10	9·30	8·08	7·39	2·34	·38	·31	·20	·49	1·30	2·62	5·23	7·23	44·87
Sibasa	443	22 44	30 28	4500	6	13·41	15·63	12·38	3·74	·41	·17	·27	·52	1·46	2·56	6·11	13·51	70·17
Wilgeboschfontein	444	23 36	29 53	3800	6	6·96	4·72	4·43	·91	·16	·11	·16	·34	·67	1·18	3·22	6·01	28·87
			Means			7·49	7·47	5·94	1·70	·38	·22	·18	·32	·81	1·86	3·76	6·60	36·72

XXIV.—*Matabeleland.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Bulawayo	445	20° 10′	28° 35′	4469	15	5·83	3·46	3·01	·62	·25	·04	·07	·04	·16	·98	4·15	5·18	23·79
Empandeni . . .	446	20 42	27 52	3300	13	6·60	3·70	2·59	·53	·24	·02	·02	·01	·07	·86	3·16	4·05	21·85
Filabusi	447	20 12	29 20	4330	9	5·79	4·13	2·22	·54	·27	·03	·22	·07	·04	1·48	2·45	5·01	22·25
Fort Rixon . . .	448	20 0	29 20	—	8	4·25	5·13	2·09	·56	·28	·04	·05	·02	·01	1·39	2·14	4·25	20·21
Gwanda	449	21 4	29 29	3000	8	5·06	3·74	2·18	·37	·09	·04	·06	·01	·06	1·28	2·64	3·83	19·36
Gwelo	450	19 27	29 49	4645	12	4·91	4·43	2·87	·75	·30	·02	·03	·16	·08	·79	4·21	5·17	23·72
Hope Fountain . . .	451	20 20	28 45	4500	14	6·84	4·14	3·60	·86	·52	·08	·15	·04	·21	1·21	3·73	4·19	25·57
Matopo Mission . .	452	20 25	28 48	5015	7	7·49	6·37	3·83	·40	·48	·02	·22	·02	·09	1·37	3·08	4·17	27·54
Rhodes Park . . .	453	20 27	28 27	4100	6	5·77	4·07	2·36	·71	·34	·04	·13	·00	·50	1·64	3·53	4·53	23·62
Selukwe	454	19 35	30 13	4800	9	8·73	10·04	5·36	1·22	·58	·25	·15	·07	·30	1·53	4·43	5·97	38·63
Tegwani	455	20 25	27 44	4500	10	5·50	3·45	2·73	·58	·11	·00	·01	·00	·05	1·08	3·15	4·30	20·96
Tuli	456	21 56	29 19	1750	11	3·39	2·24	1·45	·65	·23	·00	·01	·01	·17	·96	1·90	2·43	13·44
Victoria Falls . . .	457	17 55	25 48	2994	6	7·83	8·27	4·43	·52	·62	·04	·01	·00	·14	1·27	2·69	5·81	31·63
			Means .		.	6·00	4·86	2·98	·64	·33	·06	·07	·03	·14	1·22	3·17	4·53	24·04

XXV.—*Mashonaland.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Charter	458	19° 0′	31° 6′	—	9	7·04	7·49	2·85	·77	·39	·05	·17	·03	·03	1·56	4·24	4·64	29·26
Chilimanzi	459	—	—	—	6	7·25	6·29	4·55	1·18	·37	·03	·29	·03	·08	1·01	4·54	3·99	29·64
Chishawasha	460	17 46	31 14	4180	12	9·09	8·32	5·96	1·48	·45	·08	·03	·09	·39	1·07	4·49	5·70	37·15
Driefontein	461	—	—	—	6	6·82	6·50	2·24	1·14	·45	·08	·09	·08	·03	1·45	4·73	4·81	28·42
Enkeldoorn	462	19 3	31 0	—	7	6·70	8·39	3·11	·83	·50	·06	·14	·05	·03	1·61	3·83	4·99	30·24
Gutu	463	19 20	31 25	—	8	5·86	7·06	3·29	1·00	·39	·14	·18	·00	·03	·72	3·47	4·51	26·65
Inyanga	464	18 20	32 29	5600	7	9·43	9·34	5·03	·82	·77	·05	·30	·01	·19	1·21	3·48	5·14	35·77
Marandellas	465	18 10	31 45	5400	12	8·59	7·76	5·33	1·17	·72	·03	·12	·06	·36	1·50	4·61	6·13	36·38
Melsetter	466	19 49	32 51	5500	14	9·19	10·69	6·09	1·71	·89	·70	·81	·21	·52	1·68	5·38	6·60	44·45
Mt. Cassino	467	18 10	31 50	5000	8	7·32	6·69	4·39	·75	·73	·05	·29	·04	·25	1·89	3·34	4·64	30·38
Mt. Darwin	468	16 40	32 0	3000	11	7·83	5·79	3·35	·41	·89	·01	·01	·01	·06	·34	3·57	5·46	27·73
Mrewa	469	17 35	31 40	—	8	8·00	8·97	4·58	·61	·56	·08	·08	·05	·10	1·81	3·29	5·98	34·11
Rusape	470	18 30	32 5	4600	8	6·21	7·31	4·32	·84	·53	·21	·07	·04	·04	1·34	4·35	5·41	30·67
Salisbury	471	17 49	31 3	4880	15	7·36	7·35	4·74	1·00	·51	·05	·01	·10	·33	1·36	3·79	5·58	32·18
Sinoia	472	17 22	30 11	5200	9	7·11	8·08	3·93	·78	·63	·06	·00	·04	·06	1·06	2·71	5·68	30·14
Umtali	473	18 59	32 41	3700	14	7·68	7·76	4·08	1·21	·71	·37	·28	·28	·58	1·28	3·36	4·58	32·17
Utopia	474	18 56	32 42	3750	11	7·08	6·99	4·61	1·19	·82	·46	·46	·35	·41	1·25	3·80	4·02	31·44
Victoria	475	20 4	30 49	3200	14	6·06	5·92	2·99	·48	·32	·08	·17	·06	·12	1·29	3·43	4·76	25·68
Westridge	476	—	—	—	11	7·21	6·12	4·85	·91	·56	·03	·02	·10	·22	1·69	3·47	5·14	30·32
			Means			7·46	7·52	4·23	·96	·59	·14	·19	·09	·20	1·32	3·89	5·15	31·74

XXVI.—*Lourenço Marques and Mozambique.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Beira	477	19° 50′	34° 50′	23	12	8·62	9·13	9·50	3·56	2·05	·30	·70	·78	·36	·71	3·59	5·06	44·36
Boroma	478	16 0	33 39	614	7	5·67	5·83	2·17	·51	—	—	—	—	·08	·59	1·93	5·12	21·89
Ibo	479	12 20	40 31	33	3	6·54	5·98	4·63	6·37	·26	·54	·30	·08	·16	·59	·58	2·29	28·31
Inhambane	480	23 52	35 24	10	6	9·15	4·39	5·22	3·41	3·67	2·54	1·67	·69	·89	1·51	3·36	3·21	39·72
Inharrime	481	24 29	35 3	141	5	5·39	3·70	4·65	2·99	3·07	2·31	1·62	1·72	·31	1·53	2·03	2·98	32·29
Lourenço Marques	482	25 57	32 36	174	14	4·97	3·51	2·50	1·54	1·21	·50	·55	·45	1·16	2·55	3·49	4·23	26·66
Massinga	483	23 19	35 25	358	5	9·74	6·81	5·63	2·79	4·19	2·84	2·32	·22	·58	·59	4·00	3·17	42·87
Mopea	484	17 58	35 44	82	17	7·09	8·20	4·70	3·09	1·00	·99	1·00	·63	·03	·89	2·78	9·07	39·44
Morrumbene	485	23 41	35 23	10	5	7·47	5·29	5·57	2·68	2·79	1·25	1·24	·74	·41	1·14	1·93	2·00	32·51
Mozambique	486	15 1	40 45	—	4	8·06	8·75	5·57	2·40	1·60	1·00	·51	·70	·56	·06	1·57	5·41	36·18
Nhamussua	487	23 52	35 17	39	7	6·57	5·21	6·45	4·64	1·99	1·50	1·58	·42	1·12	1·76	2·61	3·26	37·11
Panda	488	24 3	34 43	492	5	6·60	3·38	4·42	1·72	2·32	·71	·44	·91	·94	1·29	1·67	4·39	28·78
Panga	489	23 40	35 12	—	4	3·31	1·74	6·93	2·09	2·59	1·13	·50	·62	·63	·87	1·61	3·42	25·46
Tete	490	16 10	33 38	50?	9	6·43	5·31	2·52	·50	·28	·17	·12	·04	·02	·08	2·30	5·61	23·37
Zavala	491	24 42	34 45	446	5	5·12	4·57	5·44	2·78	5·06	2·36	1·77	1·11	·75	1·07	2·05	2·76	34·84
			Means			6·72	5·45	5·06	2·74	2·29	1·30	1·03	·65	·53	1·02	2·37	4·13	33·29

XXVII.—*Northern Rhodesia and Nyassaland.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Broken Hill	492	14° 30′	28° 30′	3880	5	7·76	8·97	3·64	·62	·56	·00	·00	·00	·00	·68	3·64	6·75	32·62
Bwana M'kubwa . .	493	13 0	28 45	—	5	10·56	9·36	8·07	1·26	·48	·00	·00	·00	·00	·87	2·99	9·98	43·57
Chikuni	494	16 20	27 30	4000	8	7·74	6·44	4·01	·75	·21	·09	·04	·00	·00	·51	3·36	5·11	28·26
Fife	495	9 20	32 50	—	5	8·15	7·90	9·24	4·18	·59	·01	·00	·01	·05	·55	2·84	8·03	41·55
Fort Jameson . . .	496	13 40	32 40	—	5	8·30	10·31	7·95	1·18	·26	·01	·00	·12	·02	·19	2·70	9·84	40·88
Fort Johnston . . .	497	14 27	35 15	1430	5	8·03	5·51	4·33	2·36	·31	·16	·01	·08	·28	1·93	1·93	6·14	31·06
Kalomo	498	17 2	26 30	4100	9	7·87	6·86	3·90	·66	·02	·00	·02	·00	·53	·65	2·78	6·26	29·55
Kasempa	499	13 27	25 50	—	4	8·66	9·96	7·15	·39	·00	·00	·00	·00	·16	1·28	3·38	9·94	40·92
Lauderdale . . .	500	16 1	35 36	2540	5	18·31	19·61	14·02	12·68	5·51	3·82	2·87	1·97	3·35	4·02	7·20	15·16	108·50
Livingstone . . .	501	17 50	25 55	—	9	7·12	8·65	4·89	1·08	·44	·04	·01	·00	·07	·71	2·96	5·63	31·60
Mongu	502	15 15	23 15	—	12	7·68	9·33	5·40	·93	·11	·00	·00	·04	·07	·78	2·70	6·97	34·01
Mumbwa	503	15 0	27 5	—	9	8·23	8·75	3·44	·74	·16	·07	·01	·00	·02	·46	3·25	7·54	32·67
Nkata	504	11 36	34 18	1640	3	8·48	12·07	13·04	13·95	2·14	4·29	2·64	·60	·42	·12	3·19	10·45	71·39
Sesheke	505	17 30	24 37	—	5	7·39	4·59	4·44	·89	·00	·09	·00	·07	·00	·87	1·44	3·84	23·62
Solwezi	506	12 5	26 25	—	7	9·63	9·55	8·01	3·60	·66	·00	·00	·09	·10	1·79	4·17	10·32	47·92
Zomba	507	15 17	35 21	3130	16	12·01	10·66	7·53	4·15	1·17	·67	·27	·12	·44	1·68	5·77	10·88	55·35
			Means .		.	9·12	9·28	6·82	3·09	·79	·58	·37	·19	·34	1·07	3·39	8·30	43·34

XXVIII.—*East Africa.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Amani District .	508	5° 6′	38° 38′	3000	10	4·11	2·56	5·70	16·65	14·77	3·64	5·52	3·90	3·94	7·18	9·62	5·78	83·38
Bagamoyo	509	6 25	38 53	59	9	2·82	2·20	2·67	9·48	7·18	1·38	1·50	1·20	1·16	1·34	4·21	4·25	39·39
Bukoba	510	1 20	31 52	3900	6	4·00	5·12	10·52	17·76	15·55	1·66	2·92	2·52	3·56	4·73	8·60	6·41	83·35
Daressalam	511	6 49	39 18	25	15	3·44	1·97	4·72	12·30	7·37	1·43	1·76	1·18	1·18	1·24	2·78	3·76	43·15
Iringa	512	7 47	35 37	4860	8	5·19	5·60	5·08	1·62	·25	·03	·00	·00	·03	·05	·96	2·79	21·58
Tosamaganga .	513	7 52	35 32	5250														
Kigonsera .	514	10 50	35 3	3740	4	7·72	9·82	7·29	3·15	·76	·00	·18	·00	·12	·46	1·06	5·26	35·83
Kilossa	515	6 48	36 59	1670	5	5·22	5·11	4·50	5·08	1·67	·14	·94	·37	·24	1·02	2·59	3·27	30·17
Kilwa	516	8 45	39 25	33	4	4·73	2·39	3·11	9·87	2·02	·85	·87	·48	·83	·82	1·62	4·21	31·81
Kisserawe .	517	6 54	39 6	1080	4	5·00	1·13	2·20	9·04	4·33	1·19	1·46	·70	1·61	2·15	3·55	6·09	38·45
Kondoa-Irangi .	518	4 55	35 57	4660	5	3·83	4·45	3·27	2·65	·63	·02	·00	·00	·00	·04	1·00	4·41	20·31
Kwai .	519	4 45	38 18	4560	7	2·57	3·16	4·02	3·37	4·64	·70	1·57	·49	·38	1·59	5·35	2·48	30·32
New Köln .	520	4 47	38 21															
Lindi	521	10 0	39 44	26	7	6·51	5·62	8·26	6·87	1·58	·03	·42	·24	·48	·50	2·28	5·13	37·90
Rosahöhe .	522	10 2	39 44	269														
Mohoro	523	8 8	39 9	49	5	5·94	3·34	5·00	9·25	3·04	·91	1·11	·98	1·02	1·34	3·41	2·69	38·03
Moshi	524	3 19	37 22	3840	10	1·61	2·55	5·16	16·95	12·33	2·14	1·95	·98	·94	1·56	3·21	2·72	52·11
Mpapua	525	6 21	36 23	3380	3	4·72	3·79	3·29	1·20	·28	·04	·05	·02	·00	·00	·31	4·07	17·77
Muansa	526	2 31	32 54	3740	6	3·90	3·67	5·59	7·76	5·26	1·20	·34	1·47	1·57	2·44	4·52	5·79	43·50
Newied and Marienhof	527	2 0	33 2	4000	7	5·18	2·64	5·43	12·61	4·04	1·02	·57	3·50	1·11	3·89	4·65	7·14	51·78
Ngambo	528	5 3	38 37	3120	4	2·82	4·08	6·20	6·58	13·22	1·63	3·52	2·29	1·54	2·49	4·13	4·32	52·82
Peramiho .	529	10 38	35 29	4265	4	9·35	7·40	10·93	3·46	·25	·02	·05	·06	·22	·00	1·09	5·77	38·61
Ssongea	530	10 42	35 39	3970														
Ruteganio .	531	9 18	33 41	3740	5	7·90	7·20	9·43	26·76	12·93	1·75	1·83	·78	·84	·12	1·78	6·73	78·06
Tabora	532	5 3	32 53	4035	12	4·67	3·82	4·74	5·24	·27	·10	·00	·00	·02	·28	2·64	4·37	26·14
Tanga	533	5 4	39 7	92	14	1·17	1·85	3·51	12·01	13·57	2·71	4·42	3·06	2·78	4·16	8·06	2·45	59·75
Ujiji .	534	5 0	30 0	2800	4	4·44	2·86	4·94	8·30	1·00	·15	·00	·00	·87	1·01	3·70	4·94	32·21
Usumbura	535	3 23	29 20	2625	6	4·18	3·27	3·12	7·39	2·64	·26	·26	·02	1·13	2·37	3·60	2·84	31·08
			Means .		.	4·63	3·98	5·36	8·97	5·40	·96	1·30	1·01	1·07	1·70	3·53	4·49	42·40

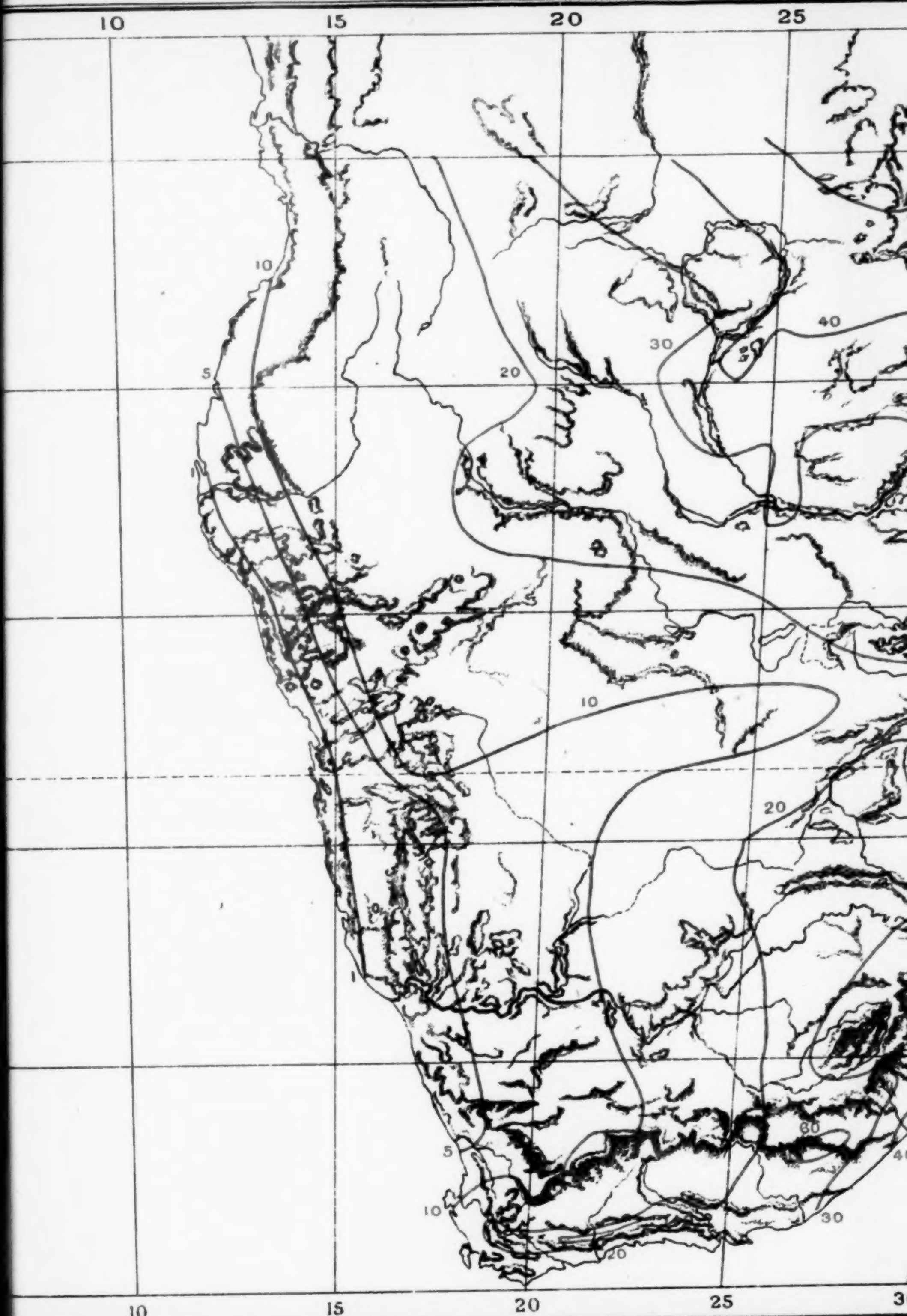
XXIX.—*British East Africa.*

	Ref. No.	S. lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Athi River	536	1° 20′	36° 50′	5800	7	·87	1·30	4·62	5·15	2·91	·82	·29	·68	·15	2·88	3·91	1·50	25·08
Eldama Ravine	537	0 7	35 35	—	7	1·11	1·48	3·26	6·65	5·67	4·36	4·09	6·22	2·25	2·39	3·07	2·26	42·81
Fort Hall	538	1 50	37 5	—	7	1·19	·92	4·96	12·53	6·03	1·25	·74	·92	·49	6·00	7·66	3·40	46·09
Kismayu	539	0 25	42 35	—	7	·00	·05	·35	2·04	7·41	3·21	2·35	·64	·45	·14	·33	·11	17·08
Kisumu	540	0 7	34 44	3800	7	1·85	4·41	5·71	6·56	4·41	3·05	2·75	3·15	·74	1·87	3·20	6·59	45·29
Kitui	541	1 22	38 1	3857	7	1·86	·45	4·19	7·95	2·10	·19	·26	·17	·05	2·91	13·15	5·63	38·91
Machakos	542	1 31	37 20	5650	7	1·30	1·16	4·45	7·69	2·65	·54	·35	·43	·07	2·65	7·65	4·98	33·96
Mackinnon Road	543	3 40	39 0	—	7	1·89	1·14	2·39	4·25	4·03	1·49	1·87	·99	·91	1·89	4·29	4·12	29·26
Makindu	544	2 20	37 45	—	7	·99	·51	2·78	3·10	1·18	·00	·01	·00	·01	1·01	7·70	4·76	22·05
Malindi	545	3 15	40 10	—	7	·34	·06	·85	8·02	17·85	6·08	4·37	1·78	1·91	2·37	2·47	·68	46·78
Mazeras	546	3 50	39 39	—	7	1·25	1·48	2·79	7·79	11·32	3·85	5·06	2·30	2·45	5·58	5·13	5·51	57·51
Molo	547	—	—	—	7	1·76	1·96	4·79	10·44	6·29	5·71	5·32	11·43	5·44	3·71	4·51	3·06	64·42
Mombasa	548	4 4	39 42	50	7	·83	·57	2·54	11·23	16·25	4·93	4·25	2·09	2·28	4·51	3·47	2·73	55·68
Muhoroni	549	—	—	—	7	2·94	4·84	5·55	12·03	6·43	5·32	2·41	6·18	4·45	4·62	4·71	5·65	65·13
Mumias	550	0 25	34 25	—	7	2·40	2·93	4·37	10·21	8·31	6·72	4·94	7·05	5·82	6·04	5·13	4·89	68·81
Mwatate	551	3 30	38 23	3009	7	1·56	1·18	3·60	5·52	2·22	·52	·49	·14	·39	·84	3·94	3·55	23·95
Nairobi	552	1 14	36 44	6000	7	2·01	1·46	3·88	8·51	5·14	1·01	·78	1·01	·55	2·64	5·45	2·89	35·33
Naivasha	553	1 40	36 30	—	7	1·10	1·10	3·02	6·02	3·13	4·49	2·48	2·88	2·08	2·40	3·16	1·96	33·82
Nakuru	554	0 15	36 10	—	7	·53	·61	2·85	5·13	4·21	2·62	3·49	4·68	2·31	2·62	2·68	1·51	33·24
Port Florence	555	0 5	34 46	—	7	1·85	4·13	6·10	6·91	4·37	2·97	2·94	3·12	1·84	2·23	3·35	6·79	46·60
Shimoni	556	—	—	—	7	1·26	·83	3·82	13·55	18·46	5·67	4·93	2·34	1·76	2·61	3·31	1·60	60·14
Takaungu	557	3 40	39 50	—	7	·34	·41	1·45	6·30	18·09	5·01	5·13	1·97	1·69	3·37	1·67	1·85	47·28
			Means			1·46	1·50	3·56	7·62	7·20	3·17	2·70	2·73	1·78	2·97	4·54	3·46	42·69

XXX.—*Various.*

	Ref. No.	Lat.	E. long.	Alt.	Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
				Ft.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Bolobo	558	2° 10′	16° 13′	1080	5	5·00	6·97	4·61	7·17	5·63	39	·04	2·68	3·78	6·54	9·57	10·24	62·60
Vivi	559	5 40	13 49	—	—	3·78	2·68	4·06	9·09	1·97	0	0	0	·04	2·95	9·33	7·09	40·98
S. Paul de Loanda	560	8 49	13 13	—	35	·91	1·43	2·44	4·92	·44	·00	—	·01	·07	·25	1·12	·73	12·32
Zanzibar	561	6 10	39 14	—	5	2·33	3·00	5·92	14·84	6·96	2·09	2·32	2·49	1·86	3·75	7·39	8·06	61·01
Antananarivo	562	18 57	47 43	—	7	10·96	10·12	6·86	2·52	·68	·35	·18	·23	·71	3·55	4·81	11·20	52·17

UTH AFRICA



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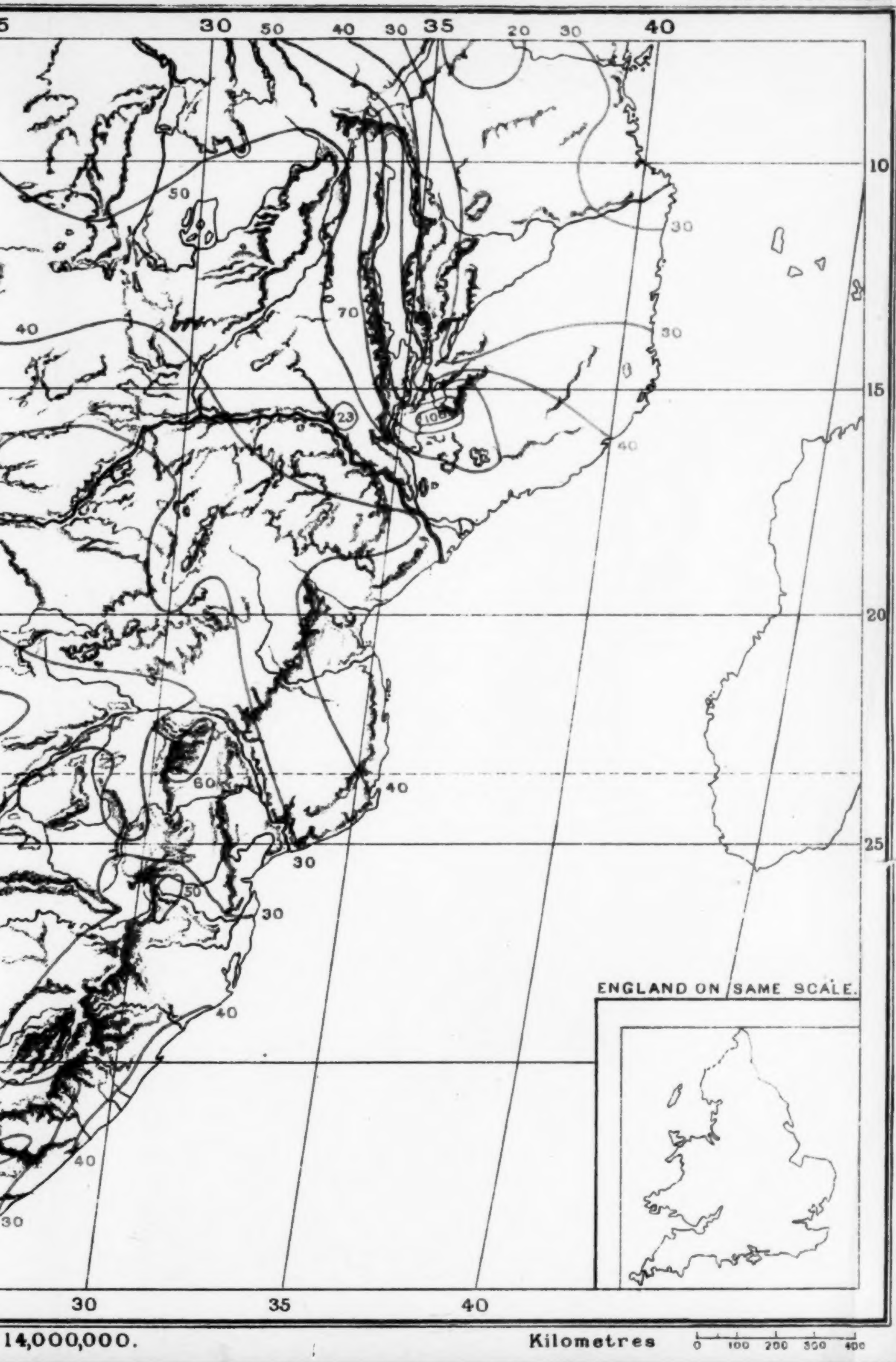
Scale 1:14,000,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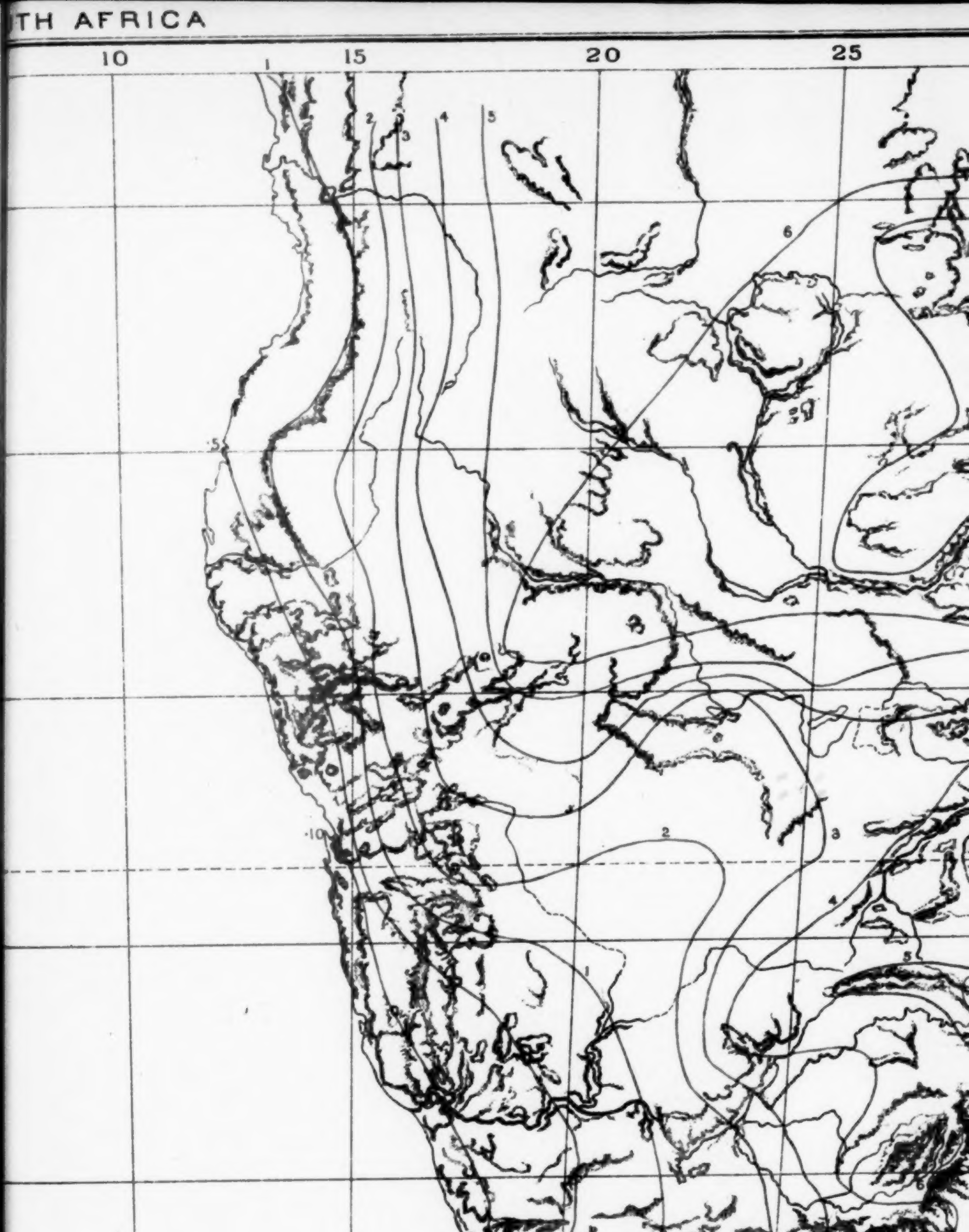
ENGLAND ON SAME SCALE.
14,000,000.
Kilometres
0 100 200 300 400



TH AFRICA
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English Miles
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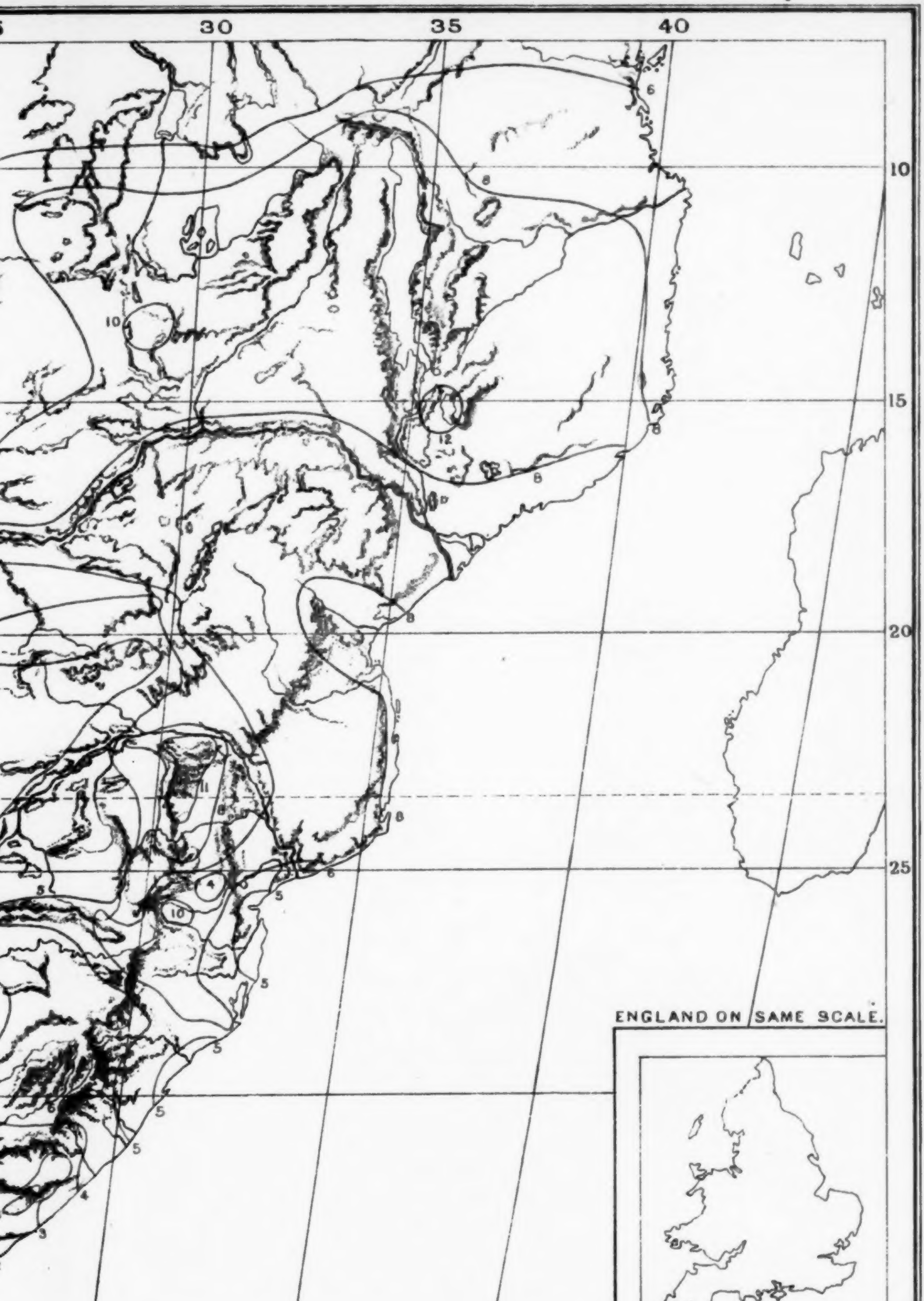
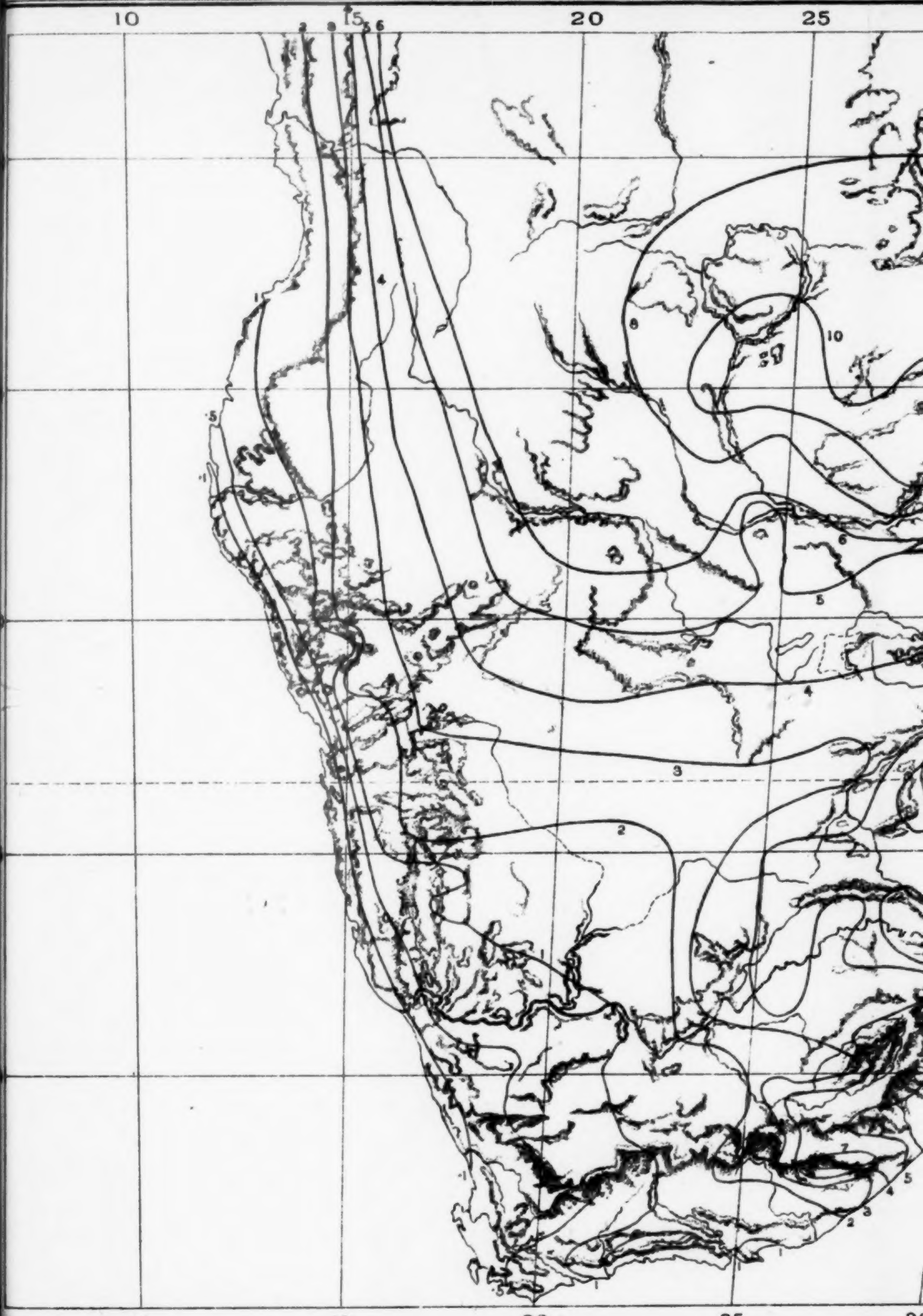


14,000,000.

Kilometres 0 100 200 300 400

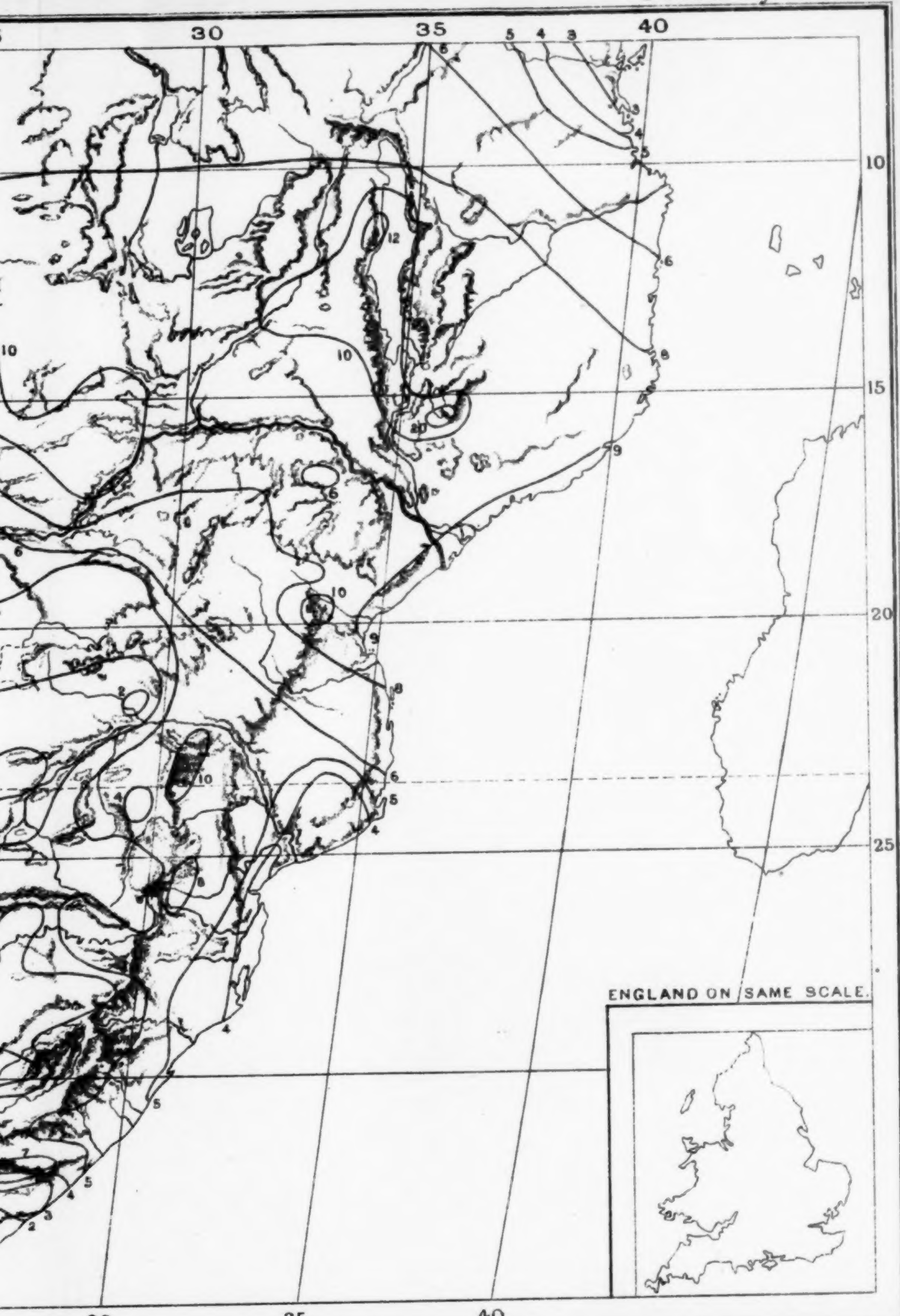
UTH AFRICA



English Miles 0 100 200 300 400

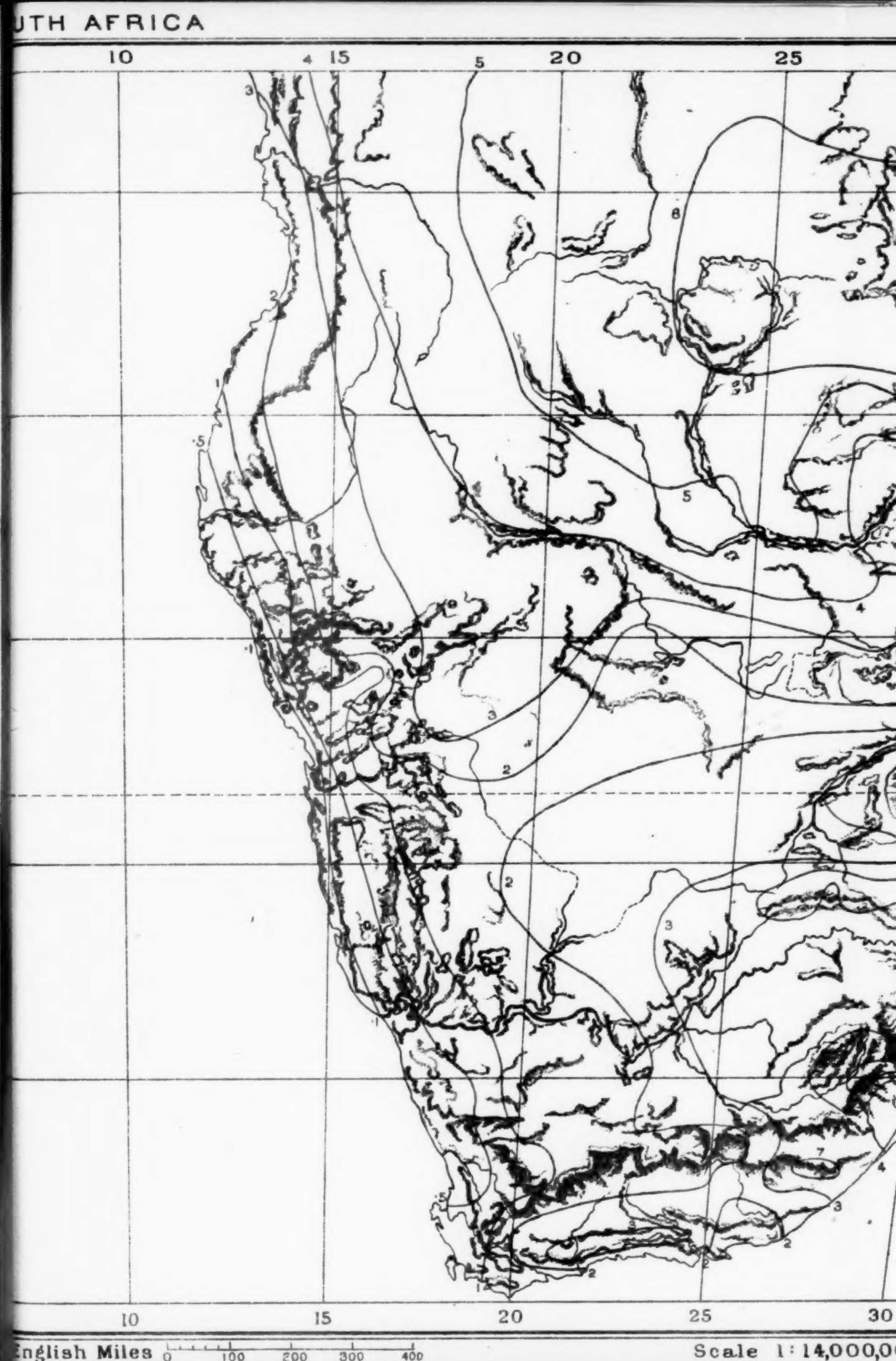
Scale 1:14,000,0

February Rainfall.



: 14,000,000.

Kilometres 0 100 200 300 400


UTH AFRICA
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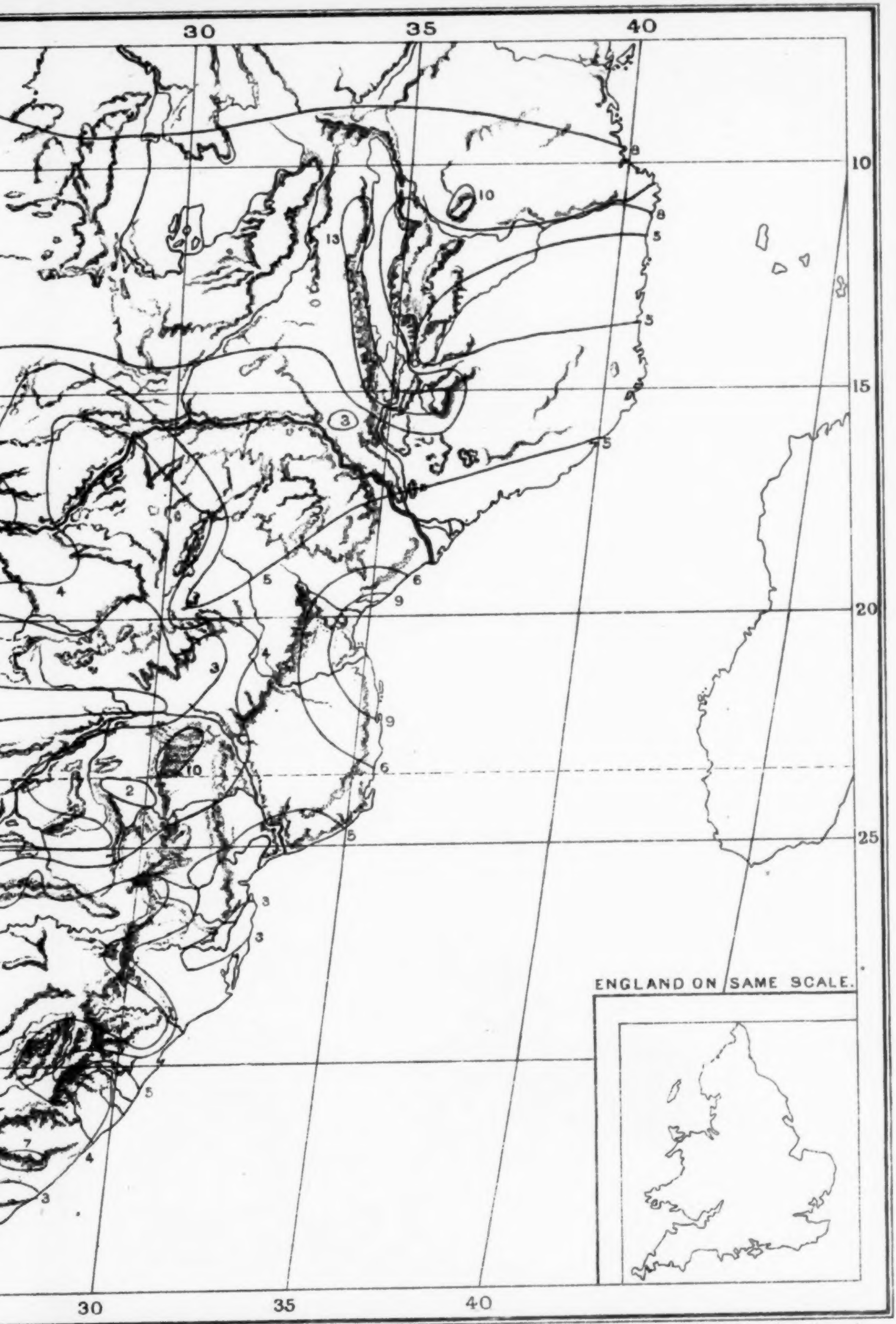
English Miles 0 100 200 300 400
Scale 1:14,000,00


30
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ENGLAND ON SAME SCALE.
Kilometres
0
100
200
300
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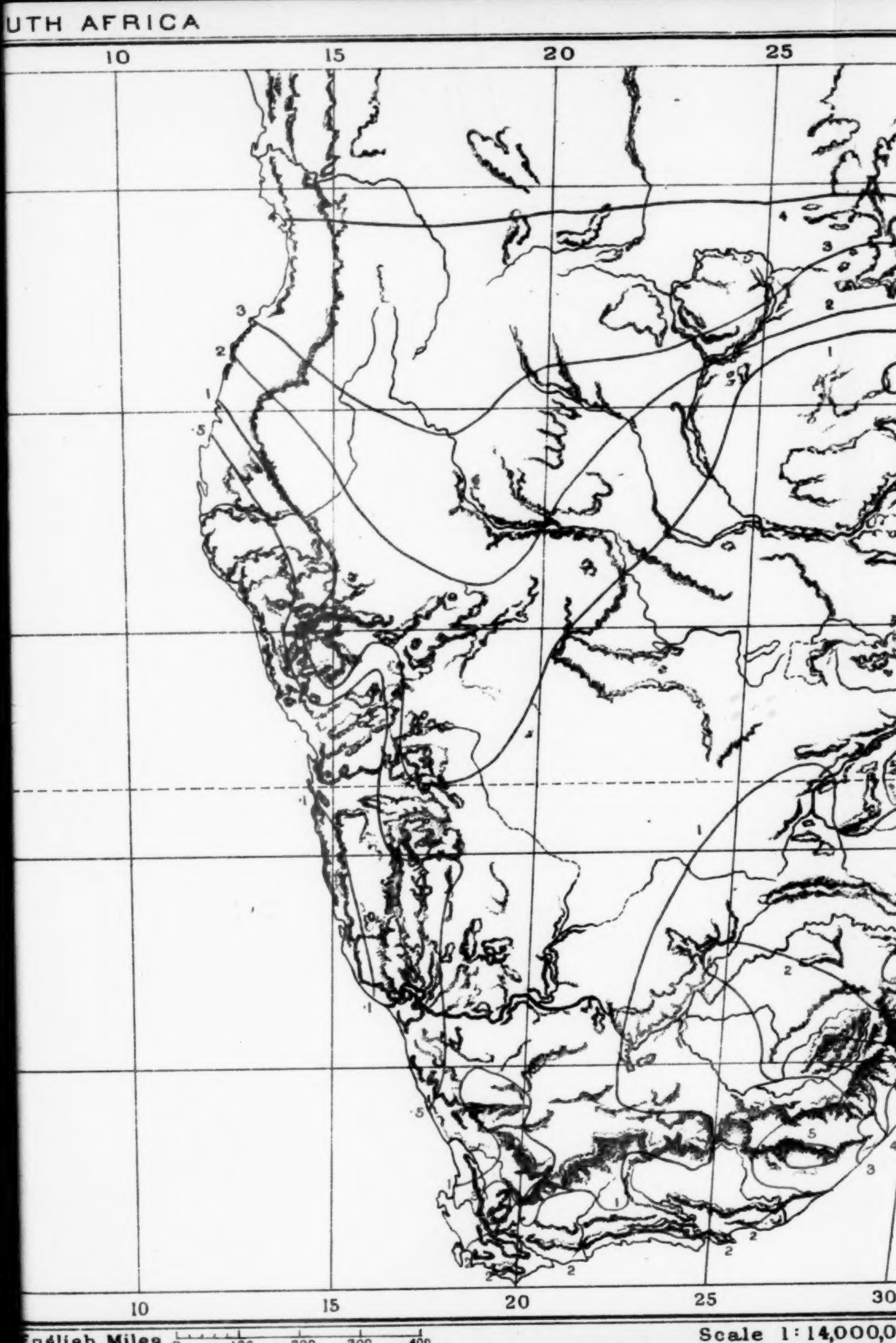
= 14,000,000.


UTH AFRICA
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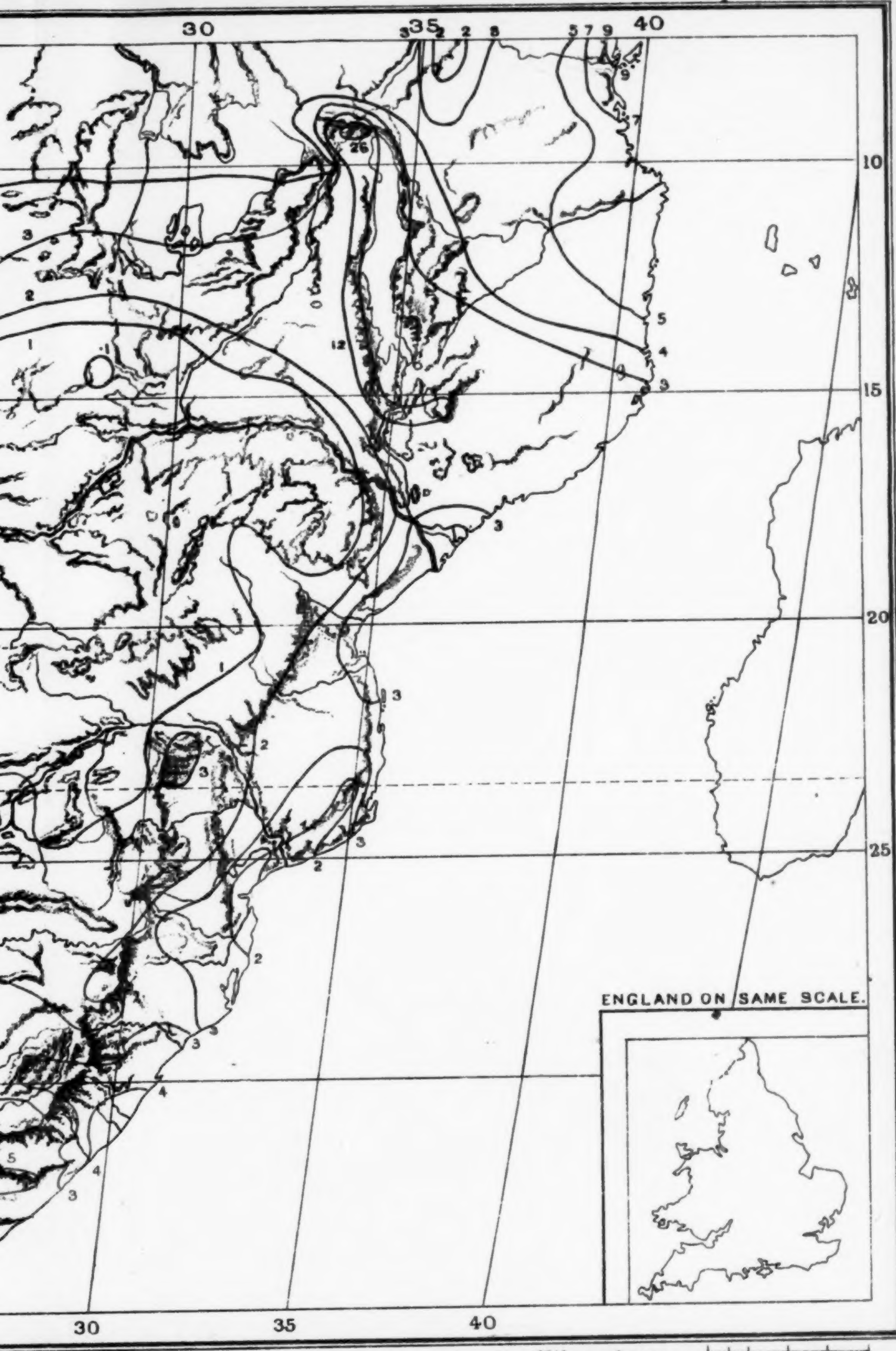
English Miles 0 100 200 300 400
Scale 1:14,000,0



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Kilometres 0 100 200 300 400

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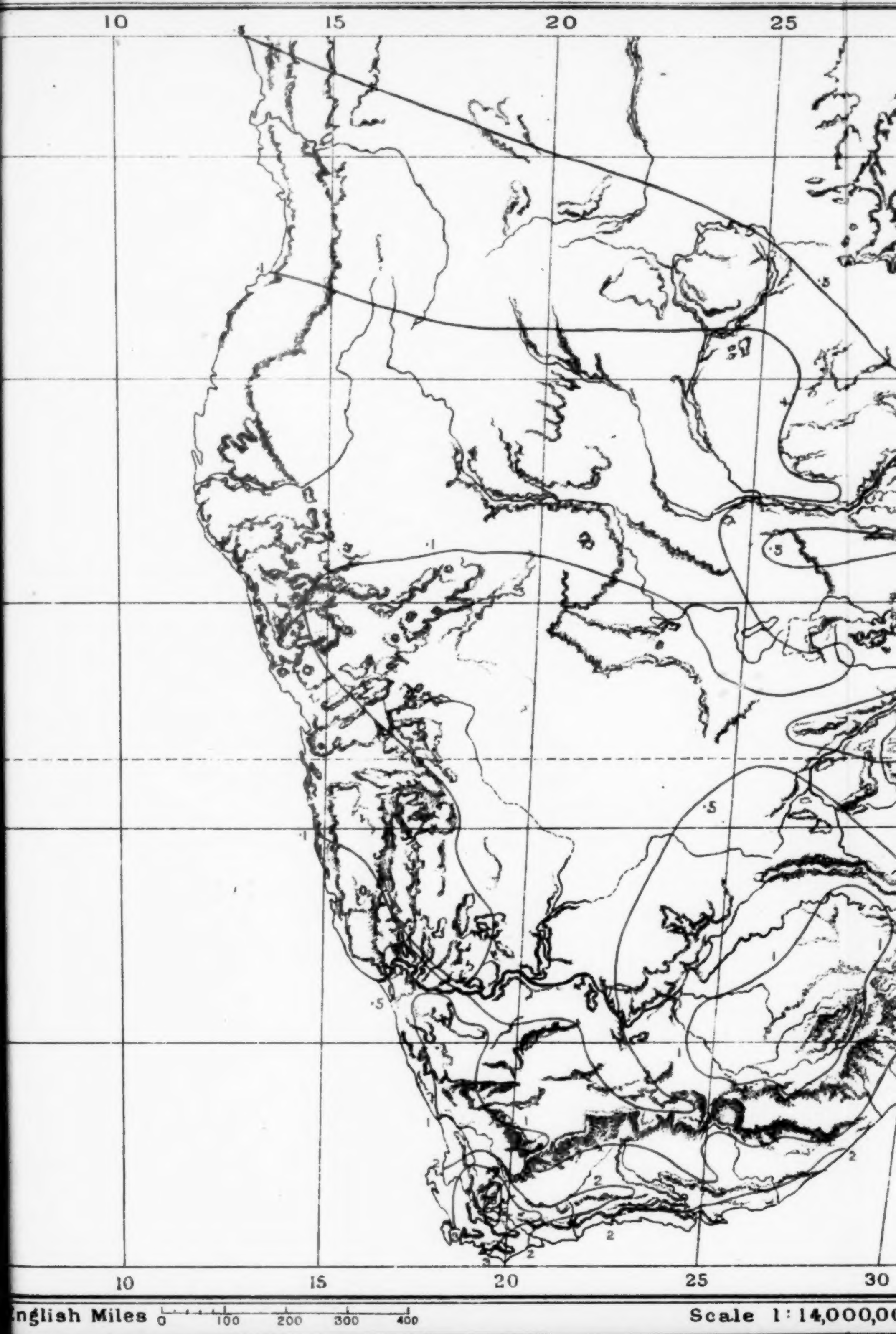
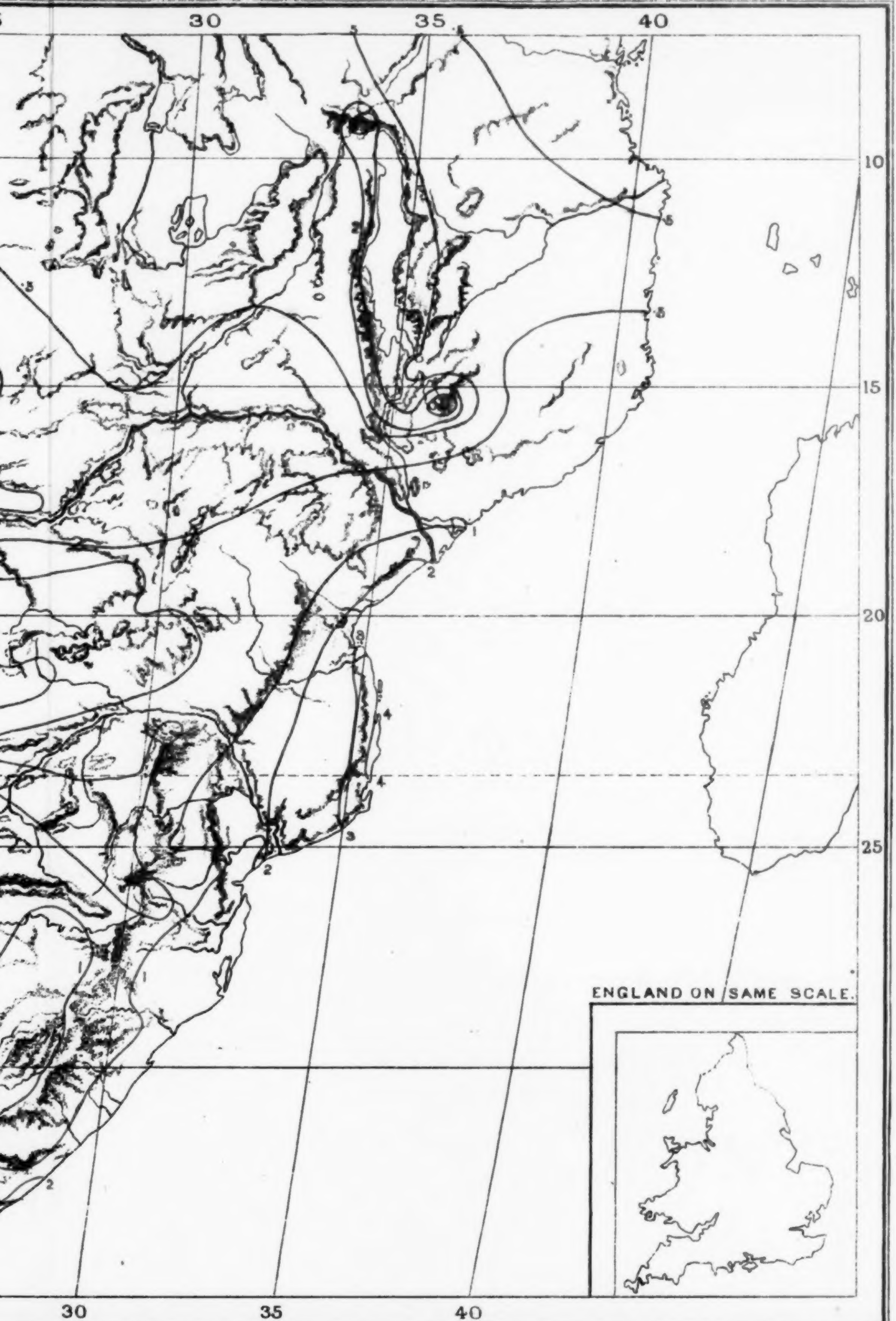


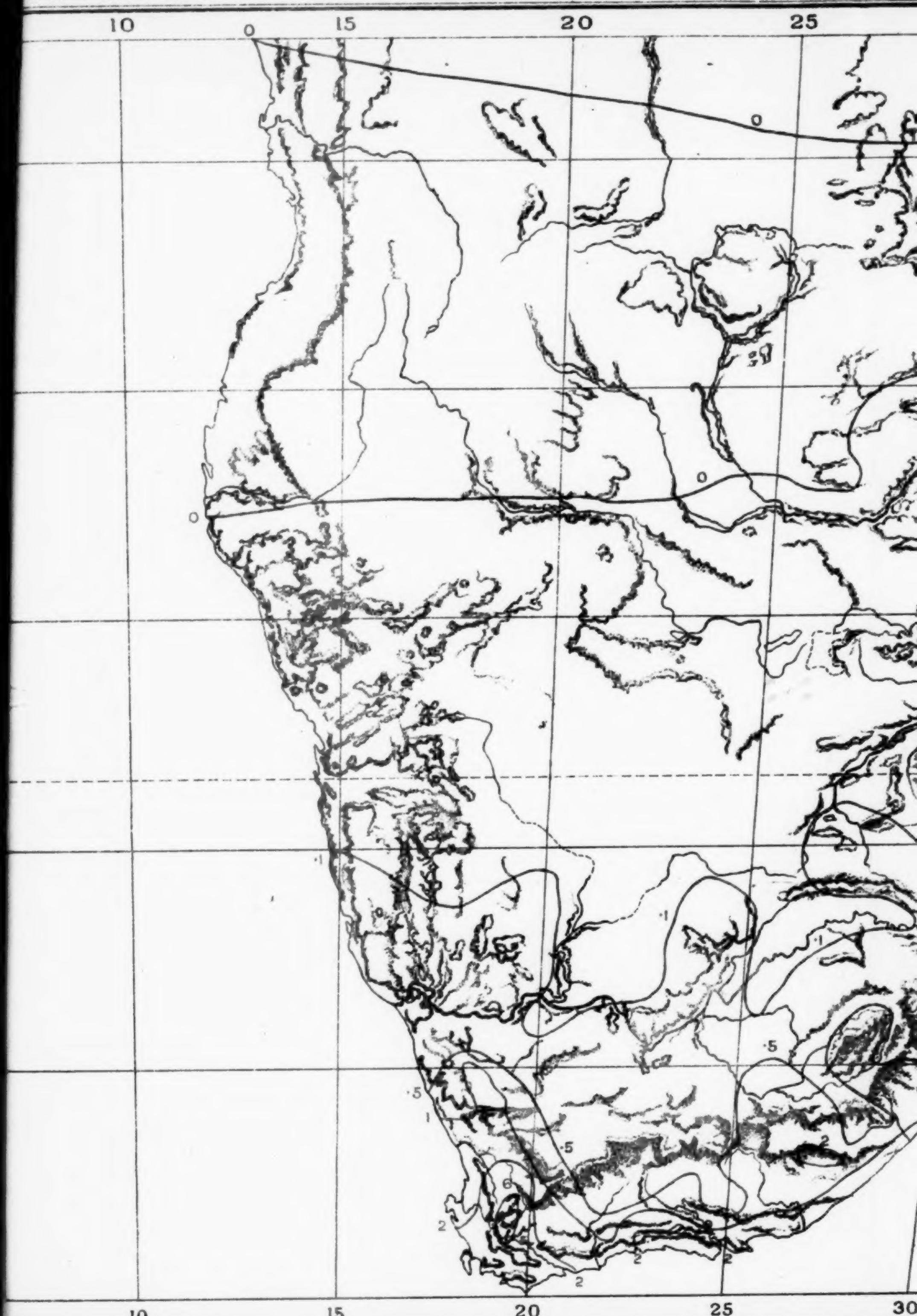
May Rainfall.



.4,000,000.

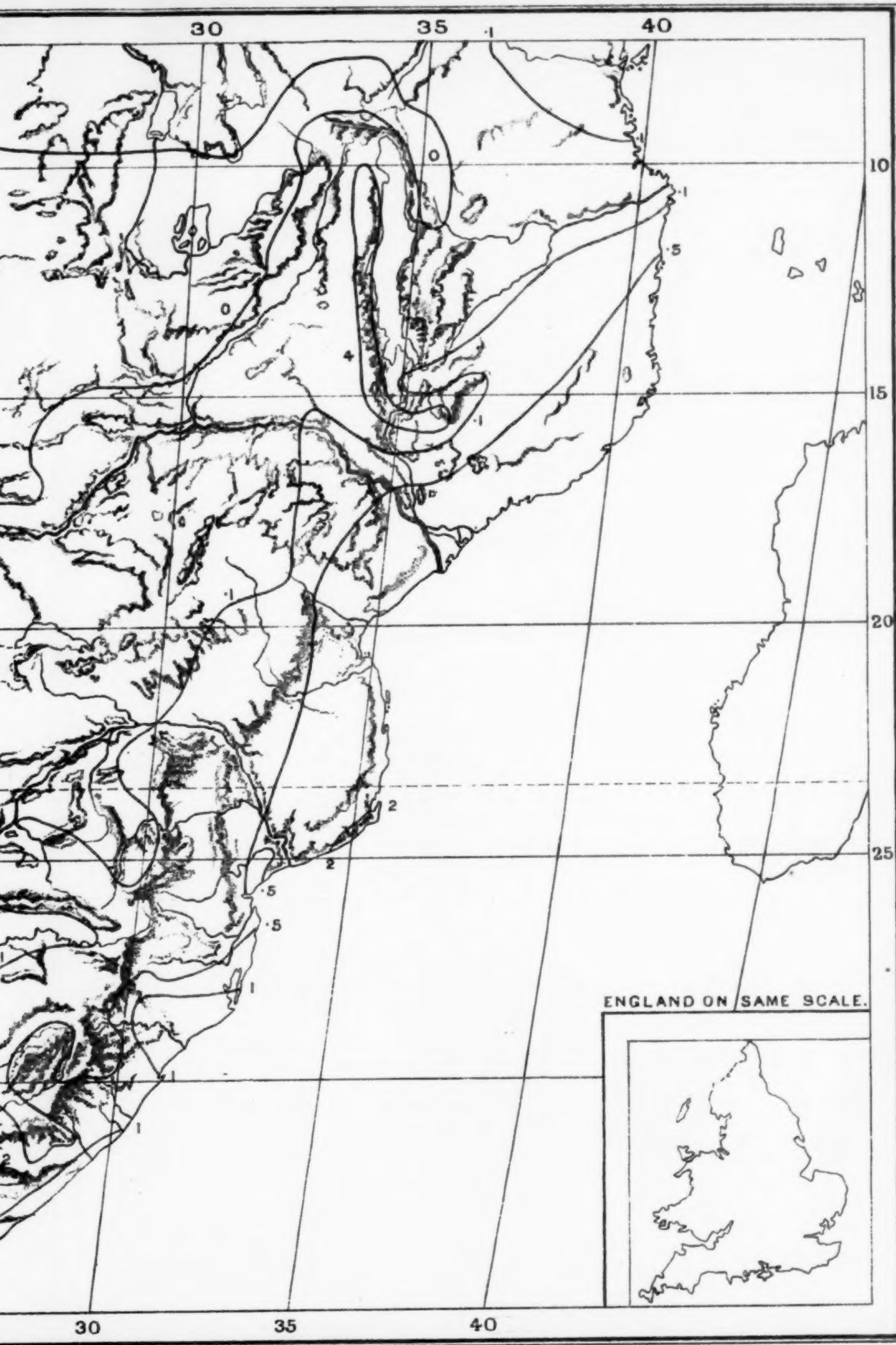
Kilometres 0 100 200 300 400

TH AFRICA



English Miles 0 100 200 300 400

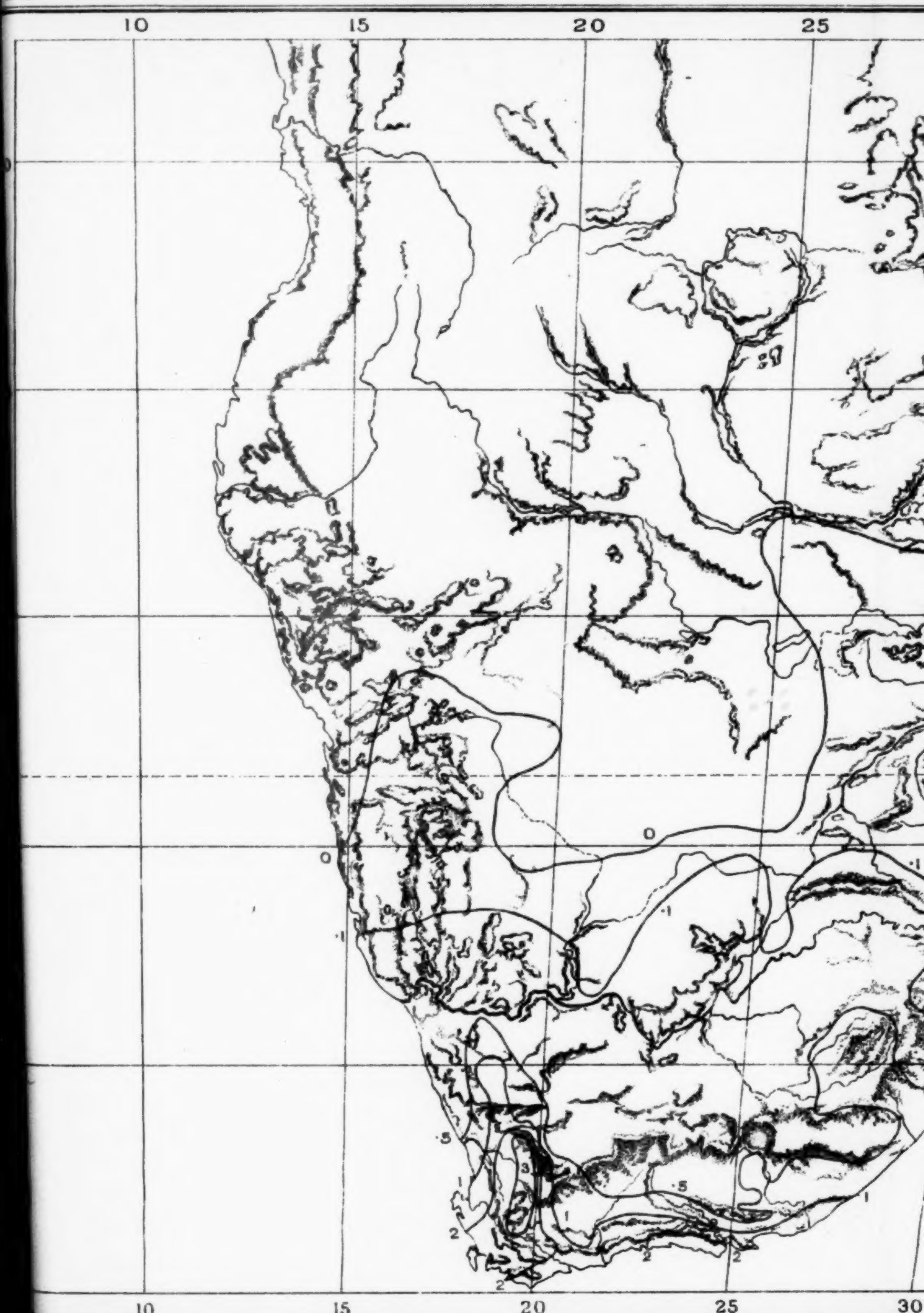
Scale 1:14,000,0



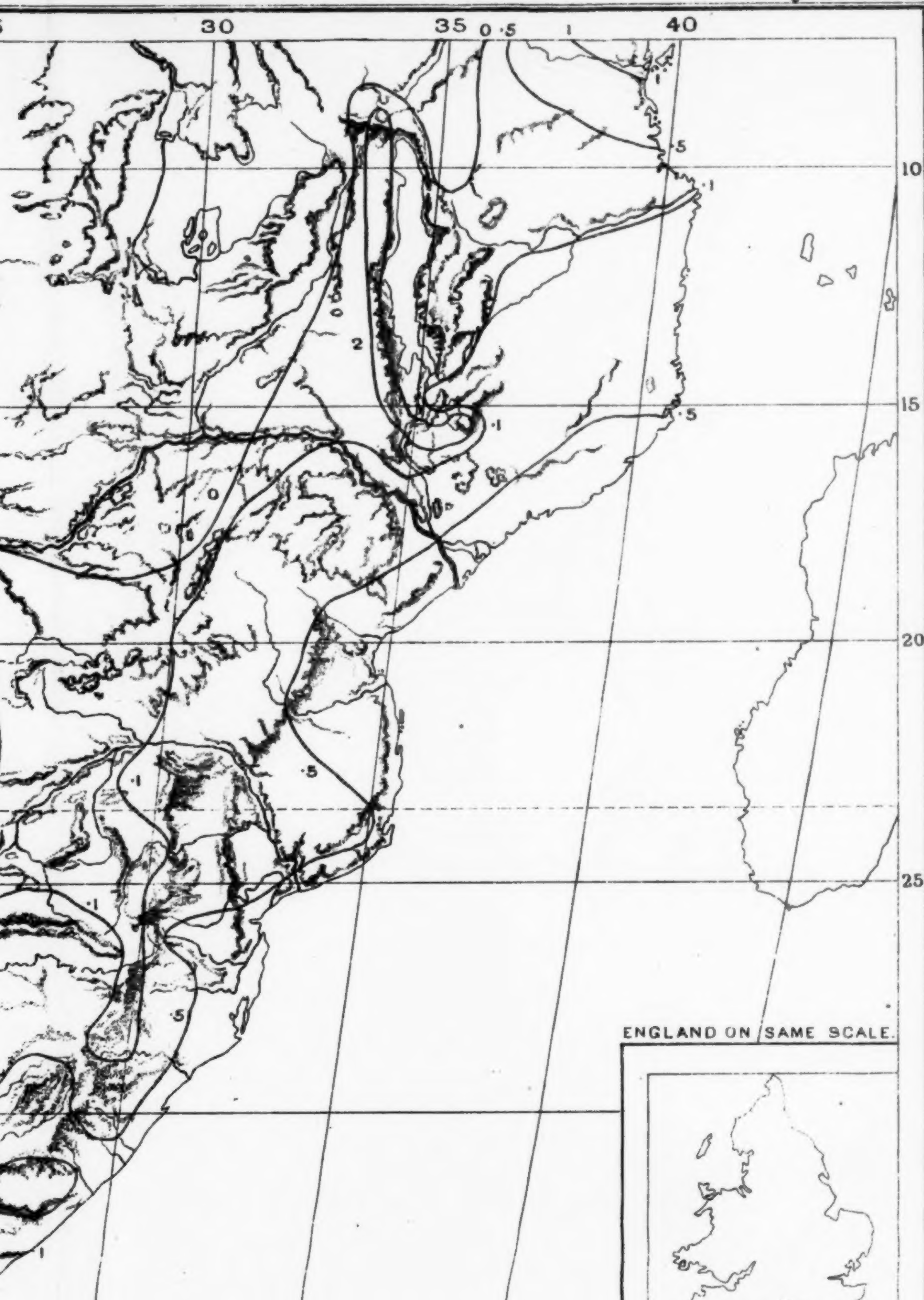
14,000,000.

Kilometres 0 100 200 300 400

OUTH AFRICA



nglish Miles 0 100 200 300 400 Scale 1:14,000,0


30
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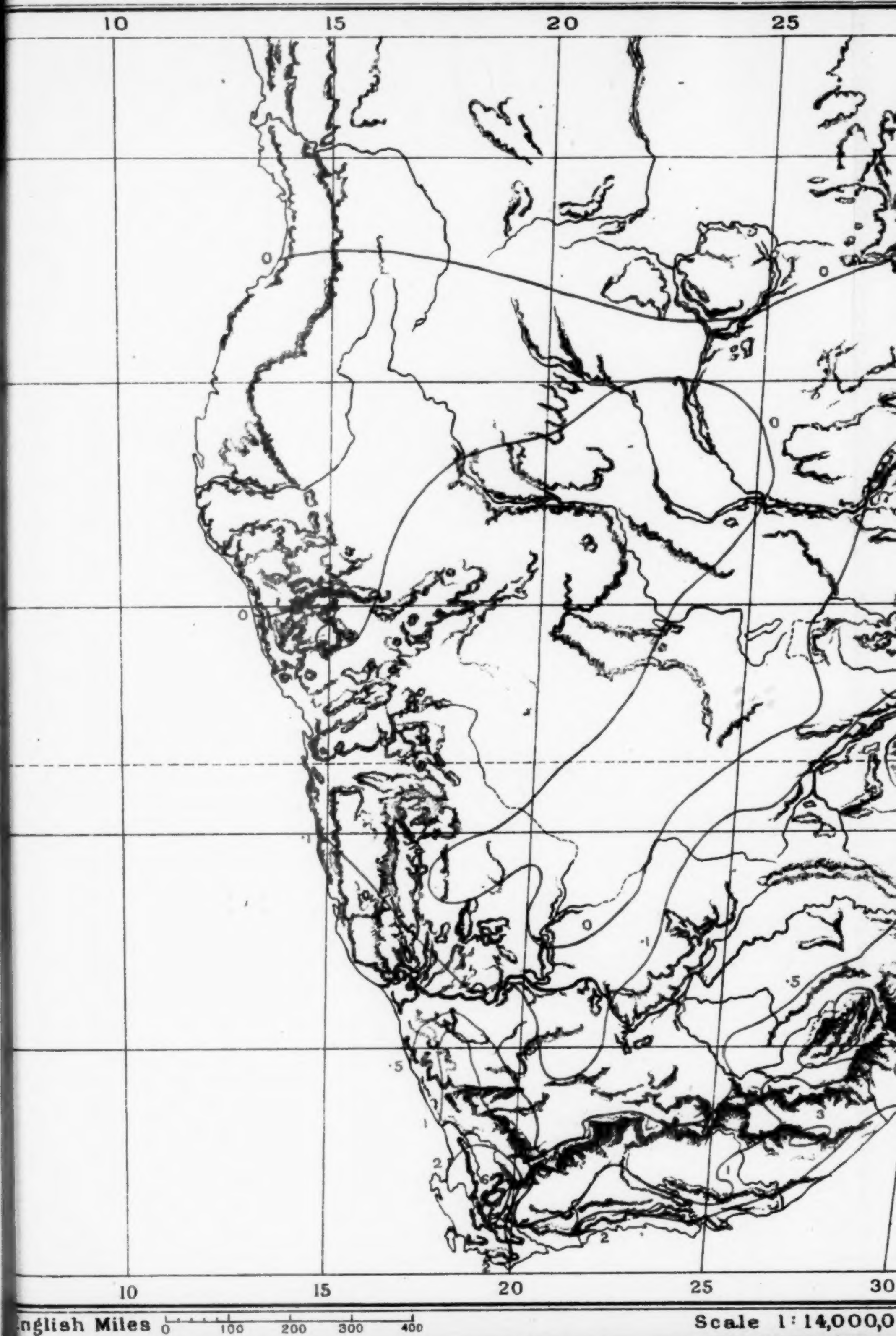
ENGLAND ON SAME SCALE.
14,000,000.
Kilometres
0 100 200 300 400

UTH AFRICA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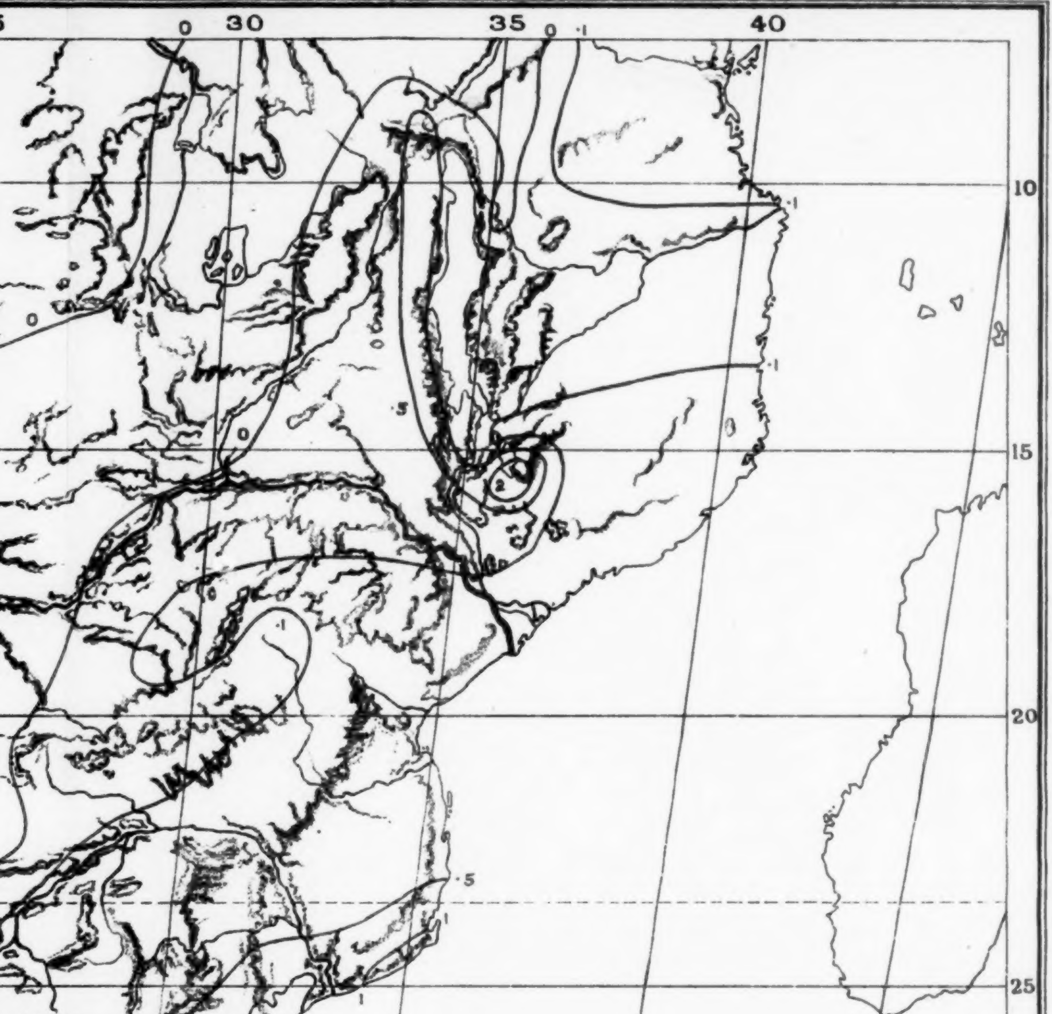
nglish Miles 0 100 200 300 400
Scale 1:14,000,0

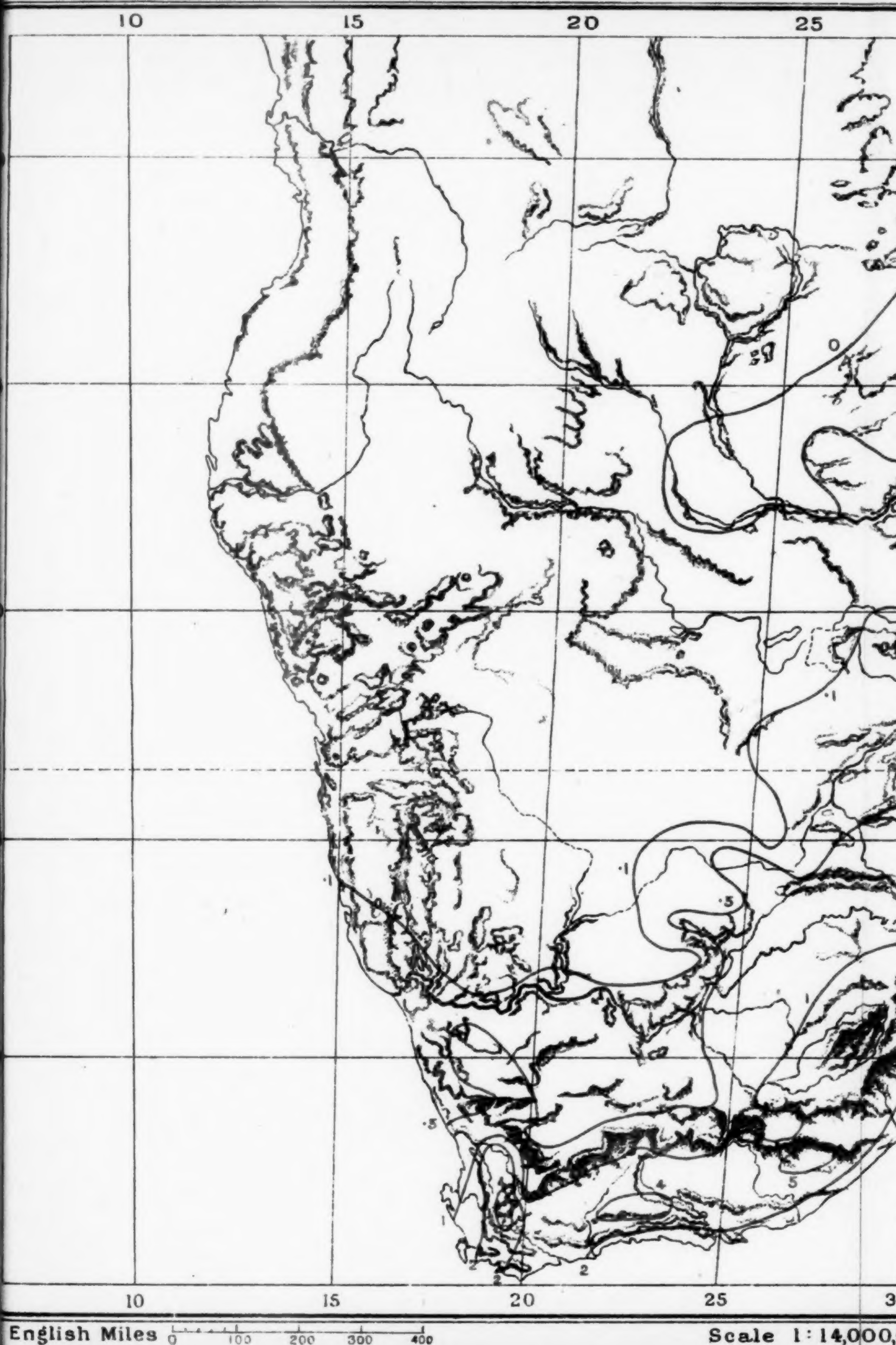
August Rainfall.



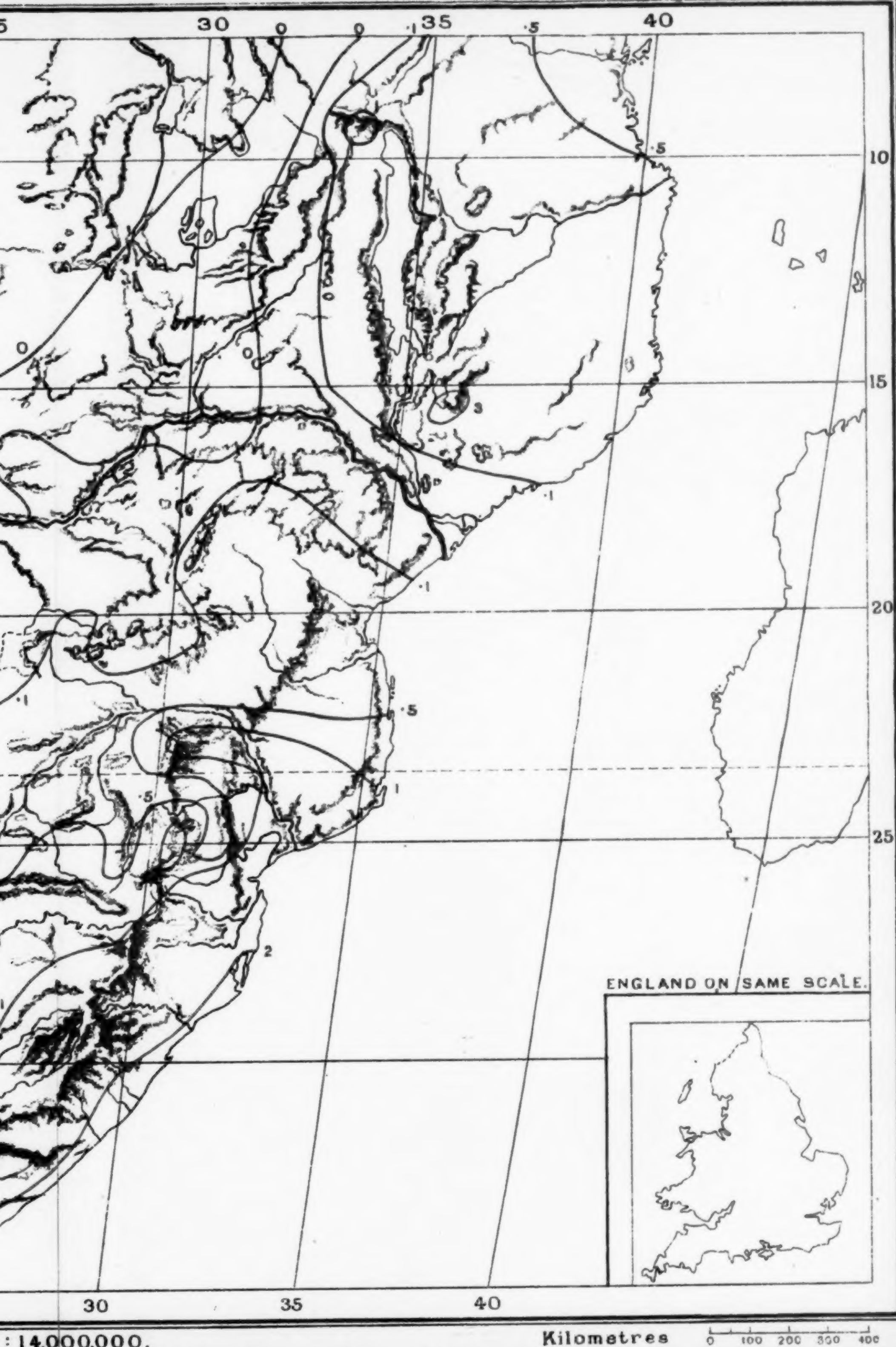
14,000,000.

Kilometres 0 100 200 300 400

OUTH AFRICA



September Rainfall.

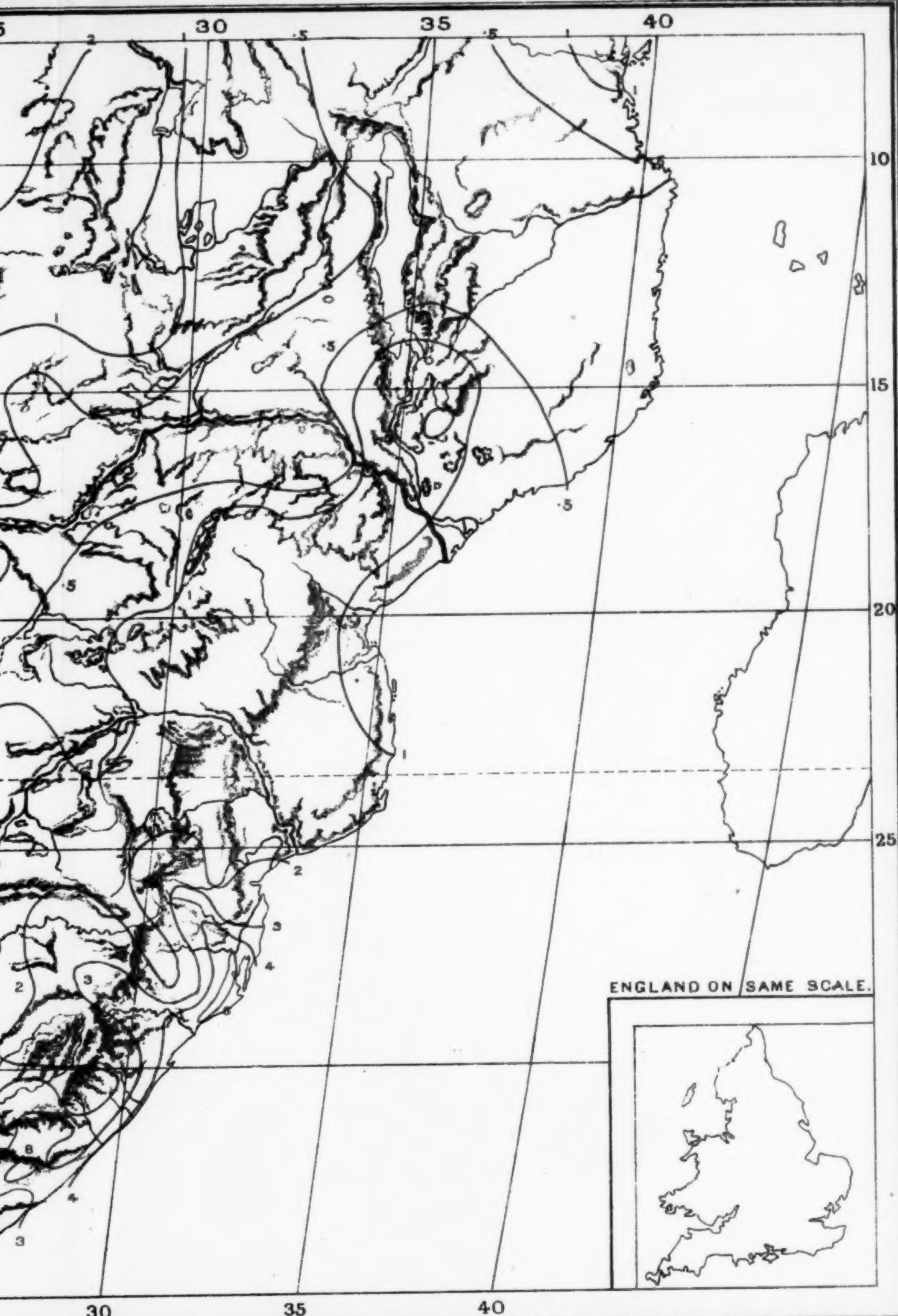


:14,000,000.

Kilometres 0 100 200 300 400

OUTH AFRICA

October Rainfall.



: 14,000,000.

Kilometres 0 100 200 300 400

OUTH AFRICA


10
15
20
25
2
3
1
·5
·1
2
1
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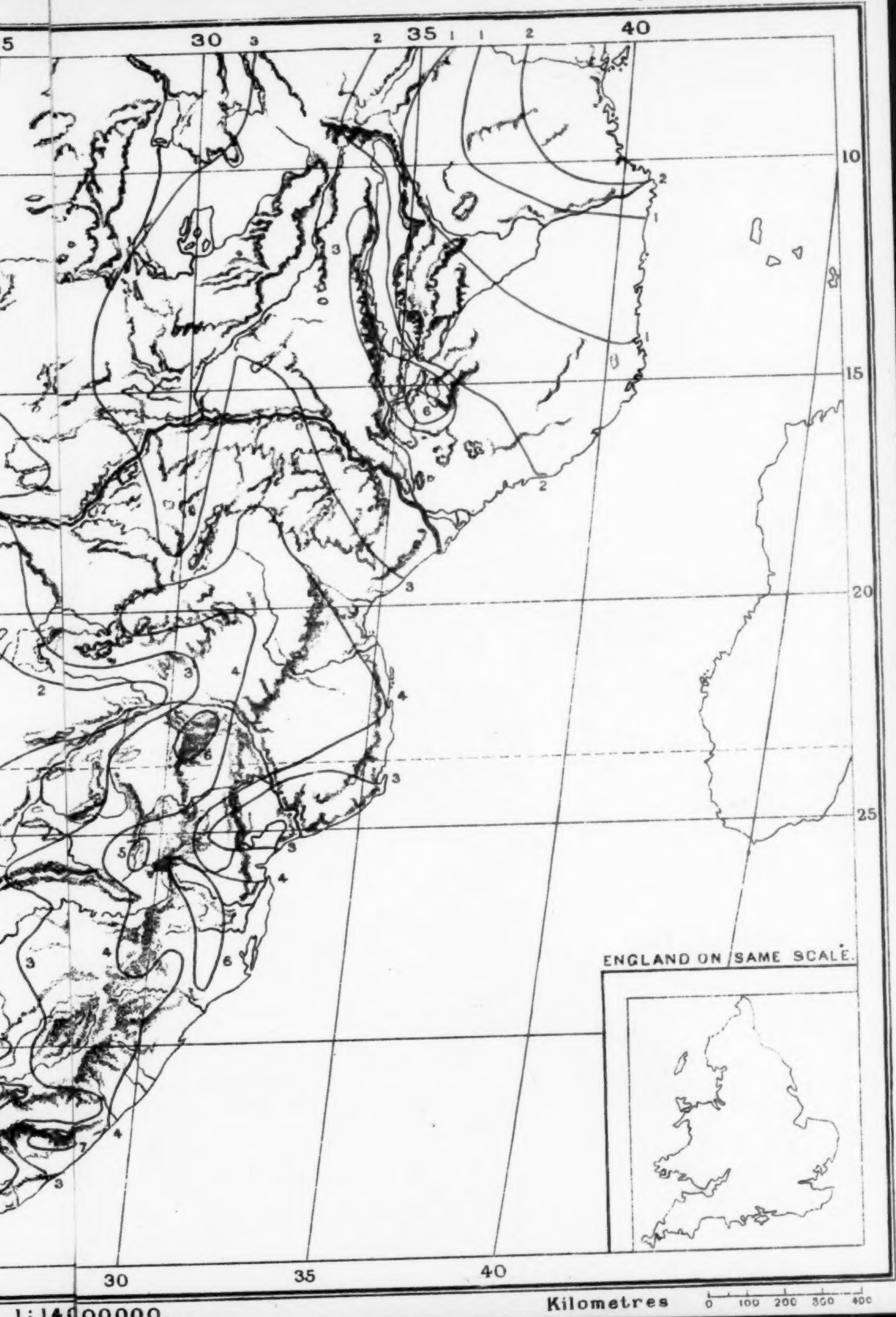
2
3
·1
·5
1
2
·5
3
2
1
10
15
20
25
English Miles 0 100 200 300 400
Scale 1:14,0

November Rainfall.



1:14,000,000.

)UTH AFRICA


10
15
20
25
10
15
20
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English Miles 0 100 200 300 400
Scale 1:14,000,

December Rainfall.

14,000,000.

Kilometres 0 100 200 300 400